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STUDY OF UPFLOW FILTER FOR TERTIARY
TREATMENT

John E. Morrison

Jefferson Parish Department of Sanitation

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STUDY OF UPFLOW FILTER FOR TERTIARY TREATMENT

by

John E. Morrison

Project 17030 DMA

Program Element 1B2043

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In the final, full-scale test phase, a flow rate equivalent to 0.5 MGD was used, and alum was injected as required to produce satisfactory turbidity levels in filter effluent. The operation was monitored constantly for flow rate, inlet pressure, water temperature and alum input; influent and effluent values for turbidity, suspended solids, BOD, COD, total phosphate, orthophosphate and pH were determined.

Filter performance was inconsistent and generally unpredictable. Alum as a coagulant was effective as an aid in contaminant reduction; however, the alum floc proved weak and its use resulted in short filter cycles. Polyelectrolytes used as coagulant aids to the alum proved ineffective in developing floc strength and extending the cycle duration. ~~(Morrison de Laureal)~~ (EPA)

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ABSTRACT

A sand-media upflow filter was installed at an existing trickling filter sewage treatment plant which receives combined domestic and industrial waste, to test its effectiveness in a tertiary treatment function. Preliminary testing was performed at three different flow rates, both with and without different chemicals as coagulants and coagulant aids, to determine optimum conditions for final, full-scale testing.

In the final, full-scale test phase, a flow rate equivalent to 0.5 MGD was used, and alum was injected as required to produce satisfactory turbidity levels in filter effluent. The operation was monitored constantly for flow rate, inlet pressure, water temperature and alum input; influent and effluent values for turbidity, suspended solids, BOD, COD, total phosphate, orthophosphate and pH were determined.

Filter performance was inconsistent and generally unpredictable. Alum as a coagulant was effective as an aid in contaminant reduction; however, the alum floc proved to be weak and its use resulted in shortened filter cycles. Polyelectrolytes used as coagulant aids to the alum were ineffective in developing floc strength and extending the cycle duration.

This report was prepared by de LaREAL Engineers, Inc., New Orleans, Louisiana, for Jefferson Parish, Louisiana, and submitted in fulfillment of Project Number 17030 DMA, under the partial sponsorship of the Office of Research and Monitoring, Environmental Protection Agency.

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SECTION I

CONCLUSIONS

In a trickling filter sewage treatment plant in which influent waste water is a combination of domestic sewage and industrial waste and in which a sand-media upflow filter has been installed:

1. The upflow filter has limited effectiveness and value as tertiary treatment on this particular waste.
2. Removal of contaminants is unpredictable.
3. Good clarity in filter effluent is possible only with chemical aids and with continual monitoring of influent and effluent water.
4. Alum is effective in assisting in the reduction of turbidity, suspended solids, BOD, COD and other parameters; however, required high dosages of alum tend to lower plant filtering cycle.
5. Efficiency of alum as an aid in contaminant removal is not constant.
6. Filtration cycles of economical duration are possible only at the expense of effluent quality.

SECTION II

RECOMMENDATIONS

In general, results of the study were unimpressive; however, there were several isolated occasions during which the upflow filter performed well and its effluent was of excellent quality for filter cycles of adequate duration. It is felt that to a considerable degree the difficulties encountered during the study and the results produced were related to local conditions that applied to the specific sewage treatment plant at which the upflow filter was installed -- primarily the effect of the varied industrial wastes that are discharged into the sewage collection system from the many plants in the area.

It is therefore recommended that further study be conducted to determine if more positive and consistent results can be achieved with the sand-media upflow filter before it can be considered for permanent installation as tertiary treatment at trickling filter plants that treat wastes of mixed domestic and industrial types.

It is recommended, further, that this type of filter be tested for its effectiveness as a means of secondary and tertiary treatment at a sewage plant that has influent waste of a predominantly domestic nature.

SECTION III

INTRODUCTION

Rapidly developing communities and rural areas have over-taxed sewage treatment facilities and required extensive plant expansion. Real estate available for treatment plant expansion and construction of new facilities has become scarce and costly. In addition, the capacities of many receiving waters to assimilate the discharge from treatment plants have become overburdened to the point that upgrading of plant effluent quality beyond the capabilities of secondary treatment has become a prime necessity. An upflow-type filter installation has the advantages of compactness and apparent economy and the potential for high-quality effluent; therefore, the successful application of such an addition to the sewage treatment process would have considerable value.

In 1968 preliminary contact was made with the Dallas, Texas, office of the Federal Water Pollution Control Administration regarding the possibility of that agency's sponsoring a demonstration project to investigate the capabilities of an upflow-type sand-media filter for tertiary application in existing sewage treatment facilities. Reports from Europe had indicated considerable promise for an upflow filter in such a function, and additional investigation had revealed little, if any, activity along this line in this country.

Further discussions with representatives of FWPCA indicated the merit of developing a program for conducting a study into the effectiveness of the upflow filter for tertiary sewage treatment. Accordingly, in June, 1969, the Parish Council of Jefferson Parish, Louisiana, made formal application to FWPCA for funds to implement such a study and on June 11, 1970, accepted a research and development grant (Project 17030 DMA) for \$98,100 or 75 per cent of eligible costs, whichever would be less.

Construction drawings and specifications prepared for the installation were approved by the Louisiana State Board of Health on December 18, 1970. On December 30, 1970, the

same documents were approved by the Federal Water Quality Administration and taking of bids for construction was authorized. Bids were received on March 4, 1971, and on May 4, 1971, a construction contract was executed between the Jefferson Parish Council and Resor Plumbing and Heating, Inc., of Metairie, Louisiana, in the amount of \$57,976.00. Subsequently, extras to the contract raised the final total construction cost to \$60,040.20.

The location selected for the program was the Camp Plauche Sewage Treatment Plant in Jefferson Parish immediately west of the city of New Orleans. This plant has two separate trickling filter facilities, the more recent of which was completed for use in 1966; and it was this newer system, which has a design capacity of 3.75 MGD and receives waste from industrial as well as domestic sources, to which piping connections for the upflow filter installation were made. Space was readily available for construction purposes, and existing on-site laboratory facilities for analytical testing of influent and effluent waste water samples were adequate.

Construction was begun in June, 1971. Operation of the upflow filter plant for the test study began in December, 1971, and was concluded early in June, 1972.

Flexibility was designed into the upflow filter system in order to use three different flow rates -- 6 GPM/sq ft (1.00 MGD), 4.5 GPM/sq ft (0.75 MGD) and 3 GPM sq ft (0.50 MGD) -- and to perform preliminary testing at these three flow rates with no chemicals and with different types and injection rates of coagulants and flocculants, in order to establish the optimum set of conditions for proceeding with the full-scale operation and laboratory analysis work. The primary effort was to be directed at obtaining results with effluent waste water from the treatment plant's final clarifier; however, the piping system was installed in such a way that the capabilities of the upflow filter could also be tested with trickling filter effluent and primary clarifier effluent if results with the final clarifier effluent were reasonably successful.

SECTION IV
UPFLOW FILTER PLANT

The upflow filter system at the Camp Plauche Sewage Treatment Plant consists of an upflow filter vessel, two sewage pumps, an air blower, air compressor, two turbidity meters, a pressure recorder, chemical tanks and injection pumps, flow metering and control devices, electrical facilities and interconnecting piping.

The filter vessel is an open-top, 12-foot diameter steel tank, as represented in section in Figure 1, manufactured

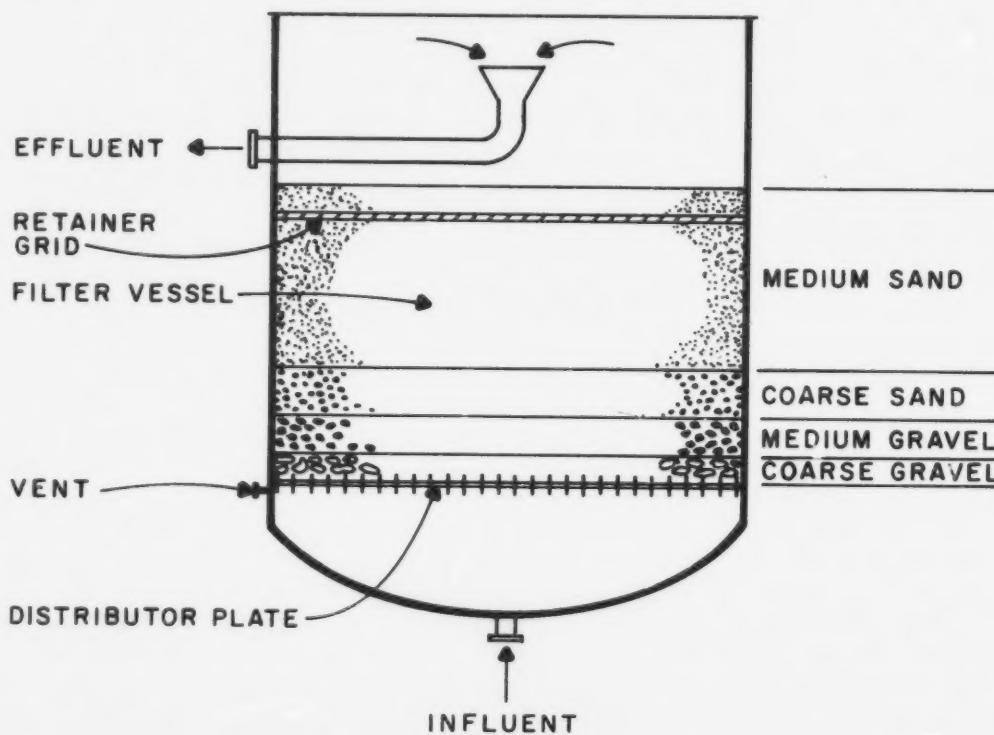


FIGURE 1 SECTION THRU UPFLOW FILTER

by the DeLaval Separator Company under the trade name of "Immediumfilter". Distribution of feed water is effected through the bottom plate, which has numerous diffuser nozzles, and additionally by the two gravel layers, which also serve as support for the layers of sand. The two grades of sand accomplish the actual filtering and "polish" the water as it passes through the upper sand levels. The grid near the top of the sand acts as a retainer for the sand during the filtration process. The filter unit, shown in Figure 2, is available with open top or with an optional cover for closed-system operation; for this project the open-top design was chosen in order to provide maximum visibility and monitoring of the effluent conditions. The access ladder to the filter top has a cage for personnel safety. The vessel is supported on four structural steel legs welded to the tank and secured to reinforced concrete pads atop timber piles.

The two self-priming sewage pumps were manufactured by Hydr-O-Matic Pump Co., and each is rated at 1150 GPM for a 45-foot differential head. One pump was used exclusively during the flush cycle; the other pump had a dual function for flush and for filter feed.

The blower unit used during the flush cycle was manufactured by Roots Blower and Vacuum Pump Division of Dresser Industries, Inc., and has a capacity of 450 SCFM.

Chemcon, Inc., supplied the two diaphragm-type, adjustable-stroke metering pumps used for alum and polyelectrolyte injection. Full capacity for the alum pump is 11 GPH; 22 GPH for the polyelectrolyte pump. Fifty-gallon polyethylene storage drums supplied chemicals to the pumps through flexible plastic hoses equipped with suction strainers and check valves. Rigid PVC tubing, with double check valves, was used on the discharge side of both metering pumps.

Influent pressures at the filter vessel intake were monitored by a Bourdon-tube gauge and a Foxboro Model 40 pressure recorder. Flow indicating and controlling functions were provided by air-operated elements manufactured by Moore Products Co.. Instrument air was supplied by a Gast Manufacturing Co. Model 4HCC-10-M40CX air compressor and storage tank.

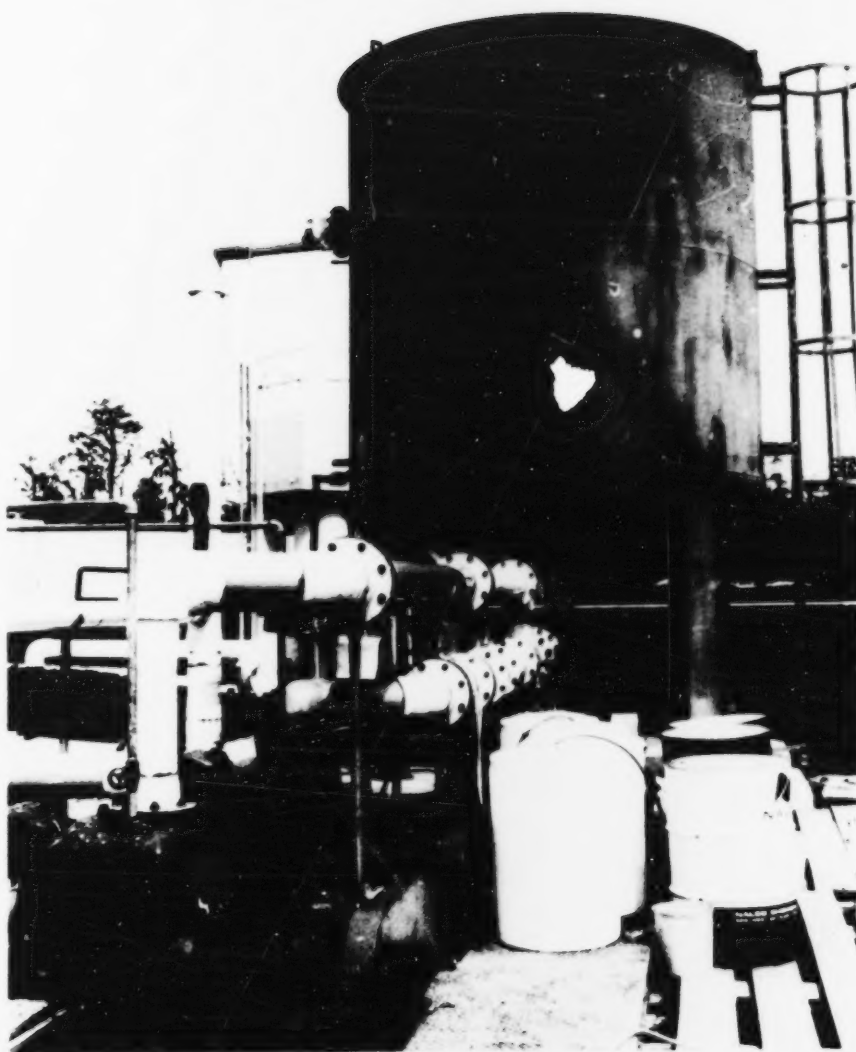


FIGURE 2 UPFLOW FILTER AND ACCESSORY EQUIPMENT

Hach Chemical Company Model 1889B Surface Scatter Turbidimeters with Rustak recorders, shown in Figure 3, were used for continuous determination of influent and effluent turbidities at the filter. In the laboratory a Hach Model 2100A Turbidimeter was used to obtain the turbidity values of the samples taken for laboratory analyses.

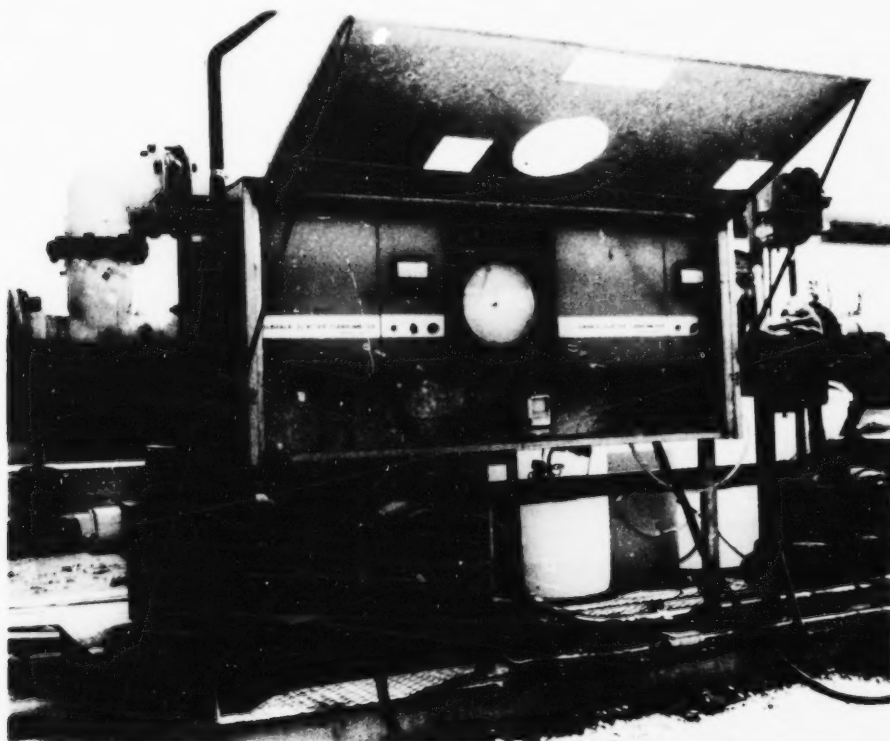


FIGURE 3 RECORDING TURBIDIMETERS TO MONITOR INFLUENT AND EFFLUENT OF FILTER

Figure 4 shows the schematic arrangement of the system as it was operated during the test study.

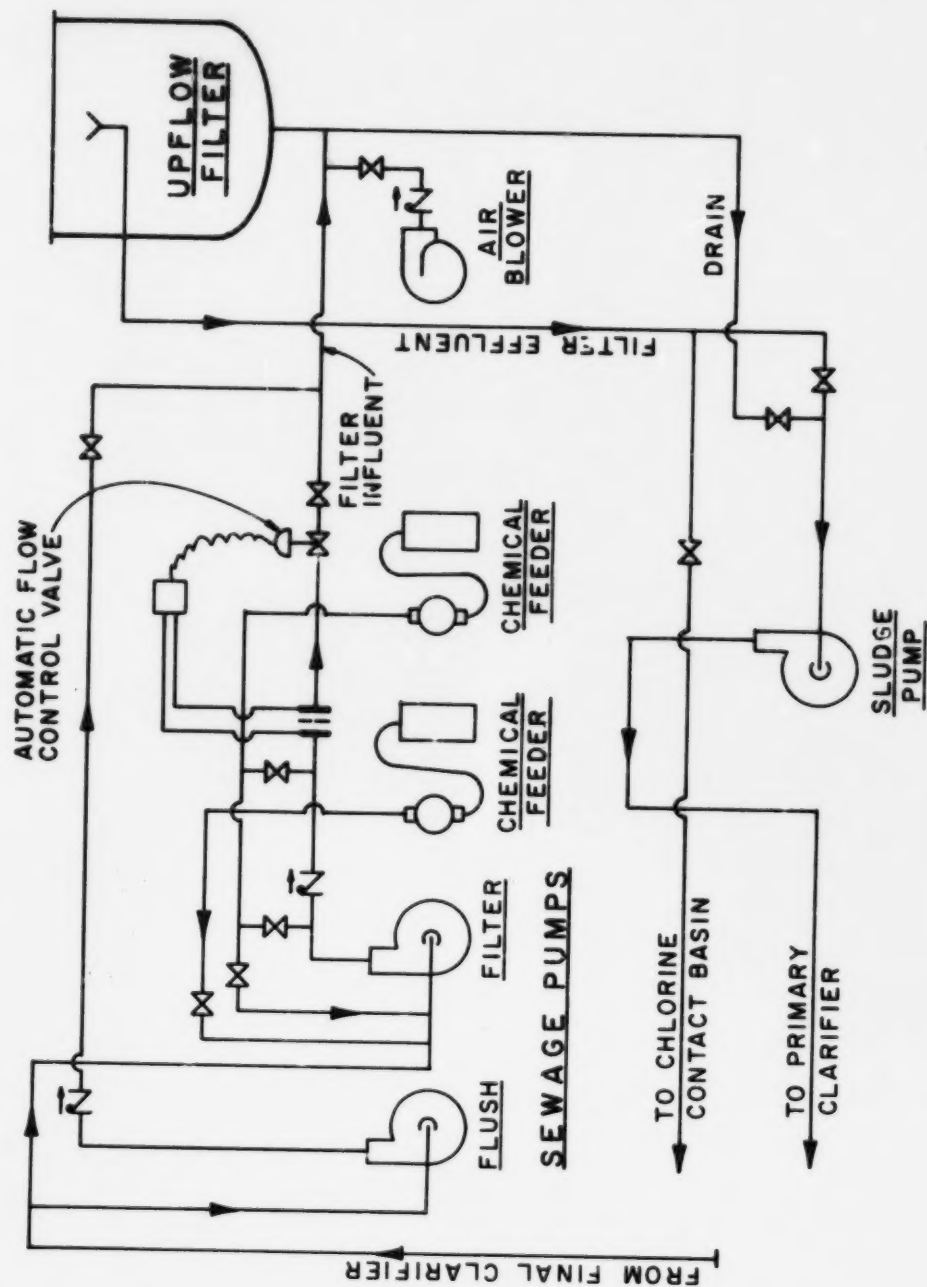


FIGURE 4 UPFLOW FILTER SYSTEM
SCHEMATIC PIPING

Flow rates were critical for proper plant operation. During the filter cycle a high column of water was required in the effluent pipe riser to assist in sample collection and to provide pressure necessary to feed water through connecting tubing and into the effluent turbidity meter. During the flush cycle this high column of water was of prime importance in avoiding undue entrapment of air in the effluent water and consequent cavitation of the pump used to dispose of the waste water to the primary clarifier.

Preliminary testing procedures involved three different filter flow rates through the 12-foot diameter vessel -- 350 GPM, 525 GPM, 700 GPM -- approximately equivalent to 0.50 MGD or 3 GPM/sq ft, 0.75 MGD or 4.5 GPM/sq ft, and 1.00 MGD or 6 GPM/sq ft, respectively, in order to determine the optimum flow rate for the conditions that were encountered. Flexibility in flow rates was required during the flush cycle also, since, due to the decreasing viscosity of the water with higher temperatures, water quantities for flushing varied directly with the rise and fall in water temperature -- 13.0 GPM/sq ft at 63 F water temperature, to 16.5 GPM/sq ft at 80 F. The different flow rates were obtained through the use of an orifice plate in the filter flow pipe line working through a transmitter and control station to automatically operate a butterfly valve as required to maintain the desired water flow. Only the dual-function filter-flush pump flow rate was varied. During the flush cycle the flow rate of the second pump, used exclusively for flushing, was maintained at a constant 1150 GPM regardless of water temperature; an orifice plate, working through a transmitter and a calibrated dial-type meter, monitored the flow, and flow adjustment was accomplished by manual operation of a butterfly valve in the piping circuit.

Effluent from the sewage treatment plant's final clarifier was used during the test program for upflow filter influent and for flushing. Upflow filter filtrate was piped to the treatment plant's chlorine contact basin inlet. Flush effluent was discharged to the treatment plant's primary clarifier, utilizing a sludge recirculating pump and piping system that normally function as permanent components in the sewage treatment plant process. At the close of each week's plant operation a strong solution of chlorine was fed through the chemical injection apparatus into the filter flow system during the flush cycle for system cleansing and preventing organism growth in the filter vessel.

The piping system for the upflow filter installation utilized 80 psi, irrigation-grade polyvinyl chloride pipe, with fiberglass-reinforced fittings and flanged joints for connection to valves and equipment. Valves for shut off and throttling were of the iron-body, iron-disc, butterfly type.

A four-foot section of clear acrylic pipe, shown in Figure 5, was installed at the intake to the filter vessel for observing conditions of influent water. At the filter outlet a six-foot sight glass was connected to the effluent pipe riser to provide a means for monitoring effluent water level in order to establish settings of manual valves and maintain proper flow rates of the leaving water during filter and flush cycles.

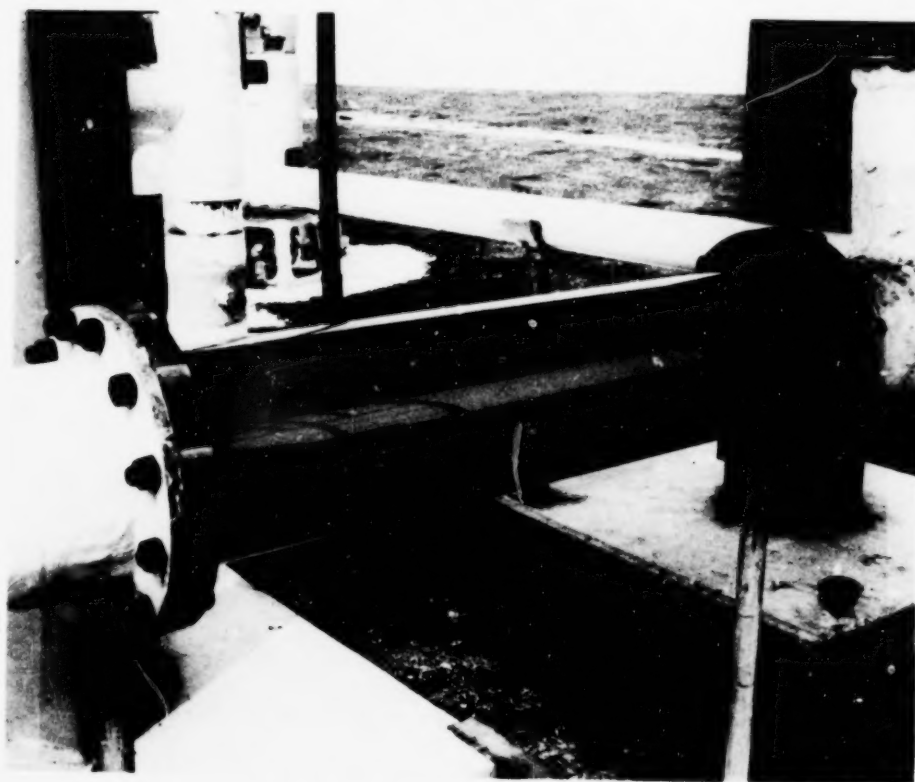


FIGURE 5 TRANSPARENT PIPE SECTION FOR OBSERVATION OF
 FLOW IN FILTER INFLUENT

The liquid alum was obtained in 55-gallon drums from a local chemical manufacturing company. The polyelectrolytes, some in liquid form and some dry, were secured from local suppliers.

SECTION V

TEST CONDITIONS AND ANALYTICAL METHODS

Plant operation was begun in December, 1971. The preliminary phase was designed to determine the most promising combination of waste water flow rate and type and quantity of chemical coagulant for the full-scale testing which would follow. During the preliminary stages, system inlet pressure, pH, turbidity and suspended solids values in filter influent and effluent water were recorded. The data shown in Appendix A for Runs 1 through 61 give the test conditions and results.

For Runs 1 through 9, water flow rates of 350 GPM, 525 GPM or 700 GPM were used, and no chemicals were injected. Runs 10 through 18, 29, 30, 38, 40 and 57 through 61 had the same three water flow rates and varying dosages of liquid alum.

Low-molecular-weight cationic polyelectrolyte in liquid form and in varying dosages was employed for Runs 19 through 26, and 39. Runs 27, 28, and 31 through 36 had alum injection in addition to the low-molecular-weight cationic polyelectrolyte.

For Runs 37 and 41 through 46, liquid alum and high-molecular-weight cationic polyelectrolyte were fed into the system. In Runs 47, 48, 49, 54, 55 and 56, alum and high-molecular-weight anionic polyelectrolyte were used. Liquid alum and high-molecular-weight non-ionic polyelectrolyte were employed during Runs 50 through 53.

The breaks in continuity for the different chemical combinations were the result of mechanical problems with the chemical metering pumps, requiring rearrangement in the schedule of operations.

Ranges of dosage for the liquid alum and the several polyelectrolytes were determined by use of intermittent laboratory jar testing of waste water samples from the sewage treatment plant's final clarifier. In all cases the jar tests indicated a relatively high demand for alum to produce

a satisfactory floc. The various polyelectrolytes were tested in combination with the alum in an attempt to strengthen the floc and thereby allow filter runs of adequate duration.

The controlling variable for determining the rate of chemical injection during a filter run was the turbidity in the filtrate leaving the upflow filter. The target value was initially set at 5 JTU maximum, predicated on the assumption that this level could be achieved with reasonably low chemical dosages. Several of the earlier runs with alum and with the combination of alum and low-molecular cationic polyelectrolyte showed promising results; however, later runs required an upward adjustment in this effluent turbidity criterion in order to maintain reasonable chemical inputs and runs of sufficient length to allow adequate sample collection for laboratory analysis.

During all filtering operations the influent and effluent turbidities were monitored constantly by the use of in-line indicating and recording turbidity meters. In order to check build-up of filtered solids in the upflow filter, inlet pressures were indicated and recorded for all runs, with a dial gauge and a 24-hour, electrically operated pen-and-chart recorder. Sample temperatures and pH values were logged.

With the exceptions of the automatic control of the filter/flush pump waste water flow rate and the 20-psi pressure in the instrument and control system air, all plant operations were conducted manually, including equipment starting and stopping, valve opening and closing, chemical mixing and adjustment of injection rate.

At the conclusion of the construction phase, technical representatives from the main office of the filter manufacturer, DeLaval Separator Company, were at the site to assist in putting the plant into operation and to establish proper procedures for the personnel who would operate the system. Two weeks' time was devoted to this activity. On four other occasions while the study was in progress DeLaval personnel visited the plant to observe and to recommend operational modifications that might eliminate difficulties that developed during the program with respect to breakthrough, short cycle, intermittently unsatisfactory effluent clarity and

other manifestations of a filter plant performance that was somewhat less successful than had been anticipated. The breakthrough phenomenon was evidenced by a sharp increase in effluent turbidity, accompanied by an abrupt drop in filter inlet pressure; floc would dislodge from the sand bed and rise, usually in cloudy, mass form, through the water in the upper level of the filter and exit through the discharge funnel.

The original intent of the upflow filter test procedure was to follow the testing of final clarifier effluent with testing, in order, of trickling filter effluent and primary clarifier effluent, and the piping was arranged to accommodate this expanded activity. However, this extension of effort was based on the assumption that results of filtering the final clarifier effluent would be highly successful -- which did not prove to be the case. The entire test program was therefore confined to final clarifier effluent.

Preliminary testing of the filter with the different chemical combinations indicated no significant improvement in turbidity reduction, suspended solids reduction, solids retention, terminal pressure or filter cycle duration by using alum and any of the polyelectrolytes in combination as opposed to using alum alone. Therefore, the decision was made to proceed into the full-scale, in-depth test operation relying on alum alone as the filtering coagulant. Laboratory test data for this phase were developed for Runs 62 through 95 and appear in Appendix B, and include values for turbidity, suspended solids, BOD₅, COD, total phosphate, orthophosphate and pH of upflow filter influent and effluent water samples.

Samples for laboratory testing were collected in standard 300 ml BOD bottles. Turbidity readings were made with a Hach Model 2100A Turbidimeter. Suspended solids were determined by use of a Gelman Type A filter with 4.1 cm glass filter discs, in accordance with "Standard Methods" procedures.

The dichromate reflux method, with mercuric sulfate added to tie up the chloride ion, was used for COD determination.

BOD₅ determinations were made per "Standard Methods", using a dilution of 5 ml for each sample.

For total phosphate and orthophosphate values, a Bausch and Lomb Spectronic 20 was employed, and procedures given in "Standard Methods" were followed. Orion Model 801 digital pH meter was the instrument used for pH determination in conjunction with Corning 476022 pH electrode and Orion 90-02 reference electrode.

SECTION VI

RESULTS AND DISCUSSION

In November, 1971, prior to operation of the upflow filter plant, laboratory tests of effluent water from the sewage treatment plant's final clarifier, trickling filter and primary clarifier were made for the purpose of determining conditions in these three effluents and setting up guidelines that could be applied to the chemical injection procedures during the test program. The jar tests that were employed indicated that alum would be required to generate a floc sufficiently effective to produce the filter effluent turbidity value of 5 JTU maximum that had been established as a basic criterion for filter performance, and that the combination of alum and cationic polyelectrolyte would achieve better results. With these background data as reference, the preliminary testing phase was begun in December, 1971.

The plan of operation was to utilize the preliminary testing phase to determine what the upflow filter capabilities would be for three different flow rates -- 350 GPM, 525 GPM and 700 GPM (3.0, 4.5 and 6.0 GPM/sq ft) -- first with no coagulant or flocculant, then with different chemicals individually and in various combinations. The observed and recorded data for filter influent and effluent turbidity and suspended solids gathered during these preliminary efforts, and tabulated in Appendix A, served as a basis for selecting the optimum values of waste water flow rate and chemical injection used in the final test phase, during which filter influent and effluent water was monitored for turbidity, suspended solids, pH, BOD₅, COD, total phosphate and orthophosphate.

Accordingly, the first nine filter runs were performed without chemical aids, with the results shown in Appendix A. Water temperatures were mild, ranging from 67 up to 74 degrees Fahrenheit. With the exception of Run 1, influent turbidities were relatively constant, varying from a low of 16 up to a high of 23 JTU.

Percentage reduction in turbidity for the 700 GPM flow rate,

averaging 41 per cent for the three runs, was somewhat lower than for the 350 GPM and 525 GPM rates, both of which averaged 56 per cent reduction. Similar results occurred in per cent reduction of suspended solids: 48 per cent for the 700 GPM rate; 53 per cent for 525 GPM; 50 per cent for 350 GPM. Heavy rains on several days during this period caused a high degree of dilution in the sewage entering the treatment plant and no doubt had a significant effect on the observed readings of turbidity and suspended solids in the influent water to the upflow filter. The shortest of these nine runs lasted 17 hours; the longest, Run 4, lasted 47 hours. The longest run also produced the highest filter pressure buildup -- 4.8 pounds per square inch. No channelling or breakthrough occurred during any of these runs.

Alum injection was employed for the next nine runs, 10 through 18, and also for 29, 30, 38, 40, and 57 through 61. For the preliminary test phase, injection of alum alone had been planned for only the first nine runs in this group -- 10 through 18; however, intermittent mechanical difficulties developed with the polyelectrolyte metering pump and additional alum-only operations were added to the schedule.

Generally, results were considered very satisfactory insofar as turbidity and suspended solids reductions were concerned for Runs 10 through 18. Six effluent turbidity values were recorded at 5 JTU or lower; seven effluent suspended solids values were down to 10 mg/l or lower. It should be noted that alum injection rates were relatively low, at 16 mg/l, or lower, with one exception. Likewise, most influent turbidity readings were low, varying from 15 up to 23 JTU; influent suspended solids ran between 25 and 50 mg/l.

It was during this series that the breakthrough phenomenon, as evidenced by a dip in the curve on the pressure recorder chart, was first observed, occurring part of the way through Runs 14 and 17; and with the breakthrough came a corresponding increase in effluent turbidity readings.

All the later runs with alum only also experienced the problem of solids breakthrough with an accompanying pressure drop. Although influent suspended solids values for this

group were comparable to those of earlier runs, the influent turbidities tended to be higher, resulting in higher accompanying alum demands and generally higher effluent turbidity readings. Suspended solids levels, both for influent and effluent, were variable.

The next stage of operations involved the use of low-molecular-weight cationic polyelectrolyte for Runs 19 through 26, and 39. Influent turbidities and suspended solids were generally higher than for preceding operations, as were the effluent values for both of these variables. Such results were in line with indications shown by the laboratory jar tests. During this series, filter breakthrough was evident only for Run 25, which reached a filter inlet pressure buildup of 6.8 psi, at which coincidental time the break occurred. None of the other runs in this series were of sufficient duration to approach this pressure condition.

Alum and low-molecular-weight cationic polyelectrolyte, injected through separate pumping systems, were used as coagulants for Runs 27, 28, and 31 through 36. During this series, effluent turbidity and suspended solids values for Runs 31, 32, and 34 and 36 were favorable; however, of these runs, for which initial inlet pressures varied between 7-5/8 and 8 psi, only number 31 was able to sustain a filter inlet pressure beyond 9-3/4 psi, the approximate gauge reading at which the other three runs experienced breakthrough. Of interest is the fact that Runs 31 and 36 were identical with respect to water flow rate and chemical injection. It was apparent that some means of strengthening the floc would be required if premature termination of the filter cycle at an unfavorably low pressure buildup were to be avoided.

Accordingly, for the next series of filter runs high-molecular-weight polyelectrolytes of different ionic classifications were tested. Again, laboratory jar tests were used to determine the ranges of dosages for the polyelectrolytes, and also for the alum which the same jar tests indicated would be required for the waste water being processed in the treatment plant at that time.

Generally, results with anionic, cationic and non-ionic polyelectrolyte in combination with alum were good insofar as effluent turbidities and suspended solids values were concerned, in most cases reaching 5 JTU turbidity or lower,

and 5 mg/l suspended solids. However, none of the high-molecular-weight polyelectrolytes exhibited sufficient ability to strengthen the floc to the degree that a reasonably satisfactory pressure buildup in the filter bed could be reached. Initial pressures at the filter inlet ranged between 7-3/8 and 8 psi; typical terminal pressures at time of solids breakthrough were 9-1/2 to 9-3/4 psi.

Influent turbidity and suspended solids values have been plotted on Figures 6 and 7 for the fourteen-week period of the preliminary test stage to indicate their relationship to each other and to determine if a trend would be apparent. In general, the values for turbidity and suspended solids within a particular week ran parallel to each other; however, for weeks 5, 6, 7 and 8, covering the entire month of February, 1972, the parallel relationship was not maintained. It was also observed that during any week there was no consistent tendency for either variable to rise or to fall.

The preliminary test series concluded with Run 61. Selected results from the preliminary test series are shown in Figures 8-12. Each point represents an average value for filter production, percent removal or effluent quality obtained in all filter runs with the same type of chemical treatment at a single filtration rate. Since filter runs were terminated for various reasons, these data serve only as a general guide to filter performance which might be expected during operation on a similar wastewater.

Figure 8 shows that filter production per run without chemical addition is several times higher than that with alum alone or alum plus polyelectrolytes. There appeared to be a trend toward high production with higher filtration rates, however the data exhibit considerable scatter.

Figures 9 and 10 show the effect of chemical addition on turbidity removal at different filtration rates. Cationic polymer when added alone did not significantly improve clarification at any flow rate. Alum alone or with polymers increased turbidity reduction by 10-30 percent depending on flow rate. There was no noticeable benefit to filtration from use of polymers with alum, although the control jar tests indicated improved performance with polymers. Effluent turbidities were quite variable but were generally lower when chemicals were used, at higher filtration rates.

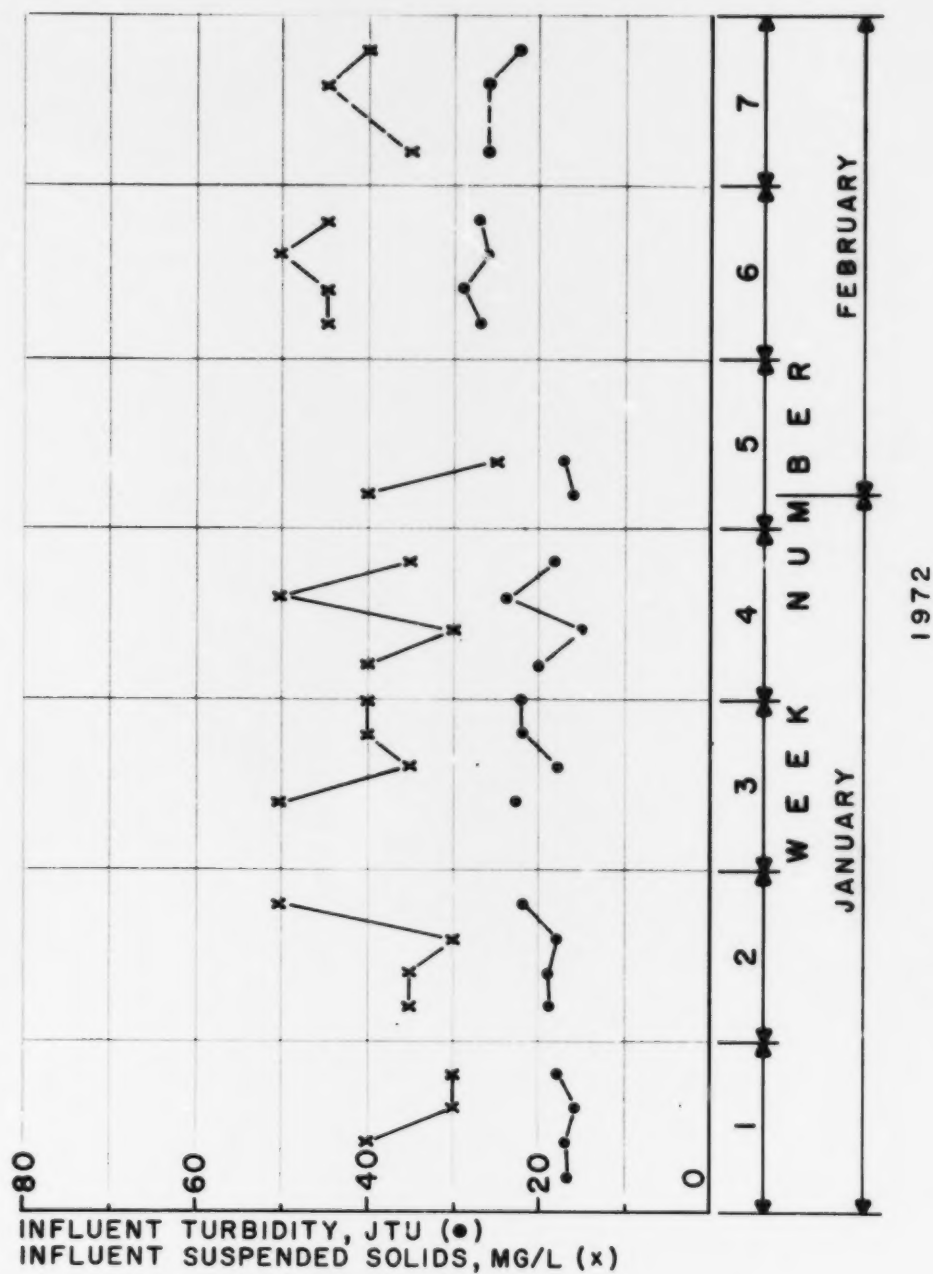


FIGURE 6 - PRELIMINARY TEST STAGE
WEEKLY VARIATION IN INFLUENT
TURBIDITY & SUSPENDED SOLIDS

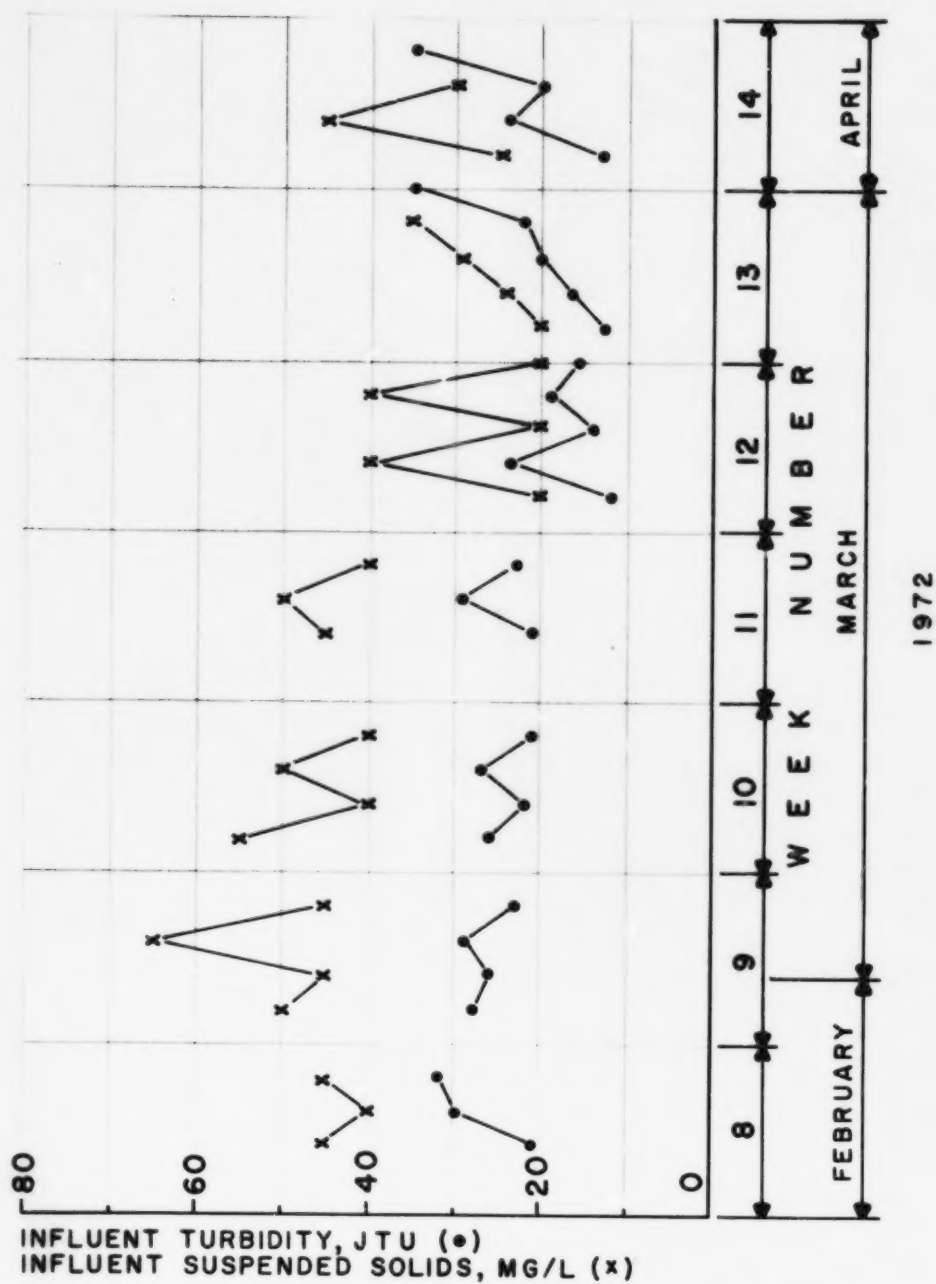


FIGURE 7 PRELIMINARY TEST STAGE (CONT'D)
WEEKLY VARIATION IN INFLUENT
TURBIDITY & SUSPENDED SOLIDS

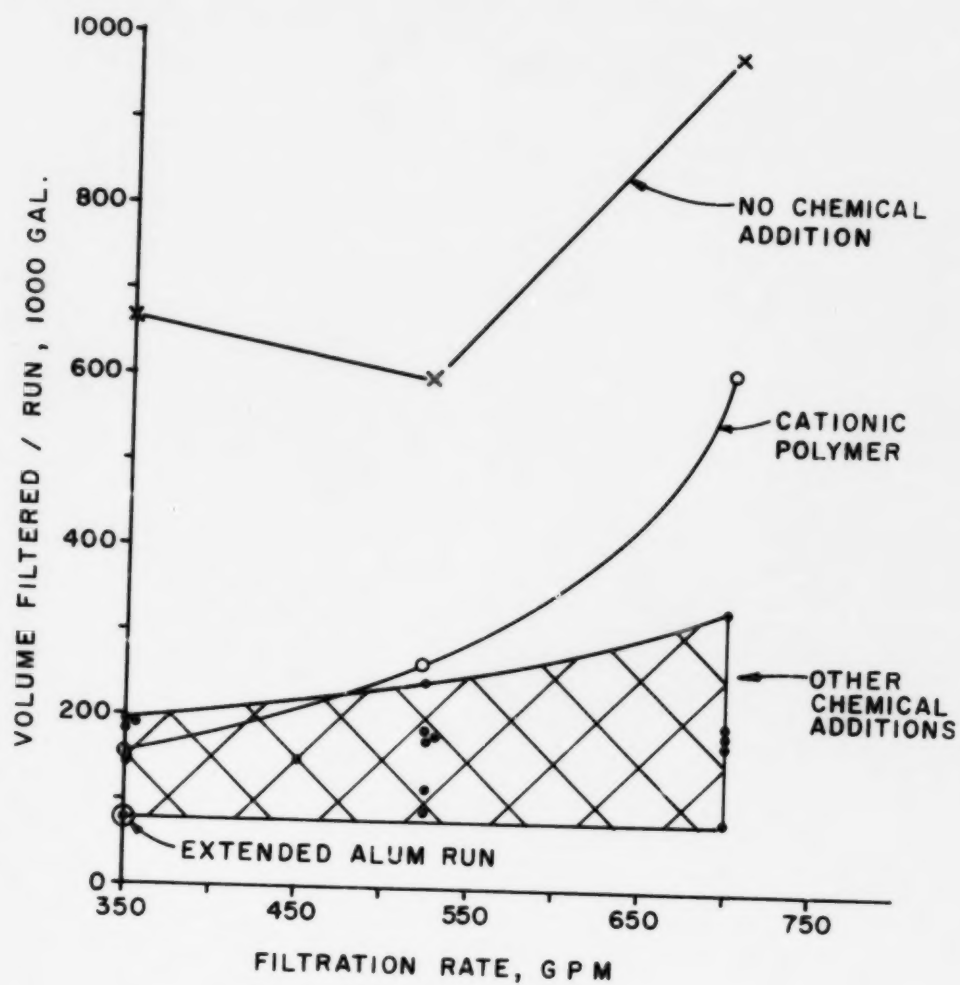


FIGURE 8 EFFECTS OF CHEMICAL ADDITION AND FILTRATION RATE ON FILTER PRODUCTION.

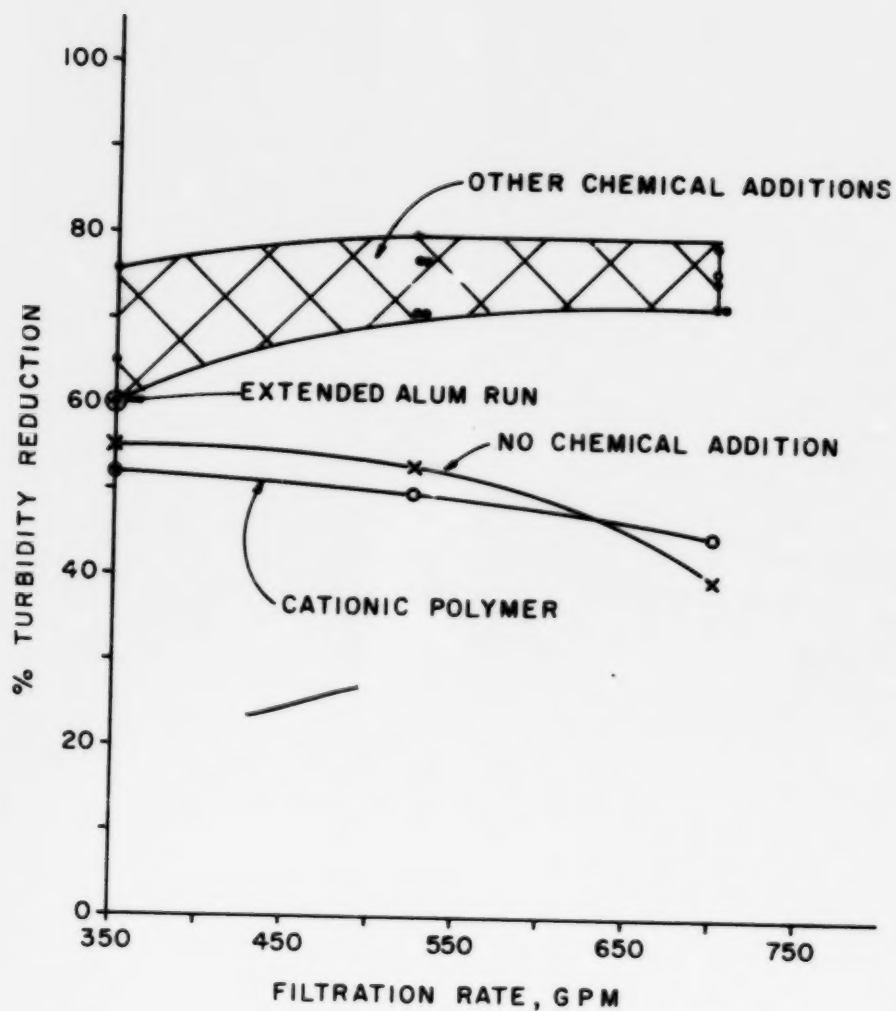


FIGURE 9 EFFECTS OF CHEMICAL ADDITION AND FILTRATION RATE ON TURBIDITY REDUCTION

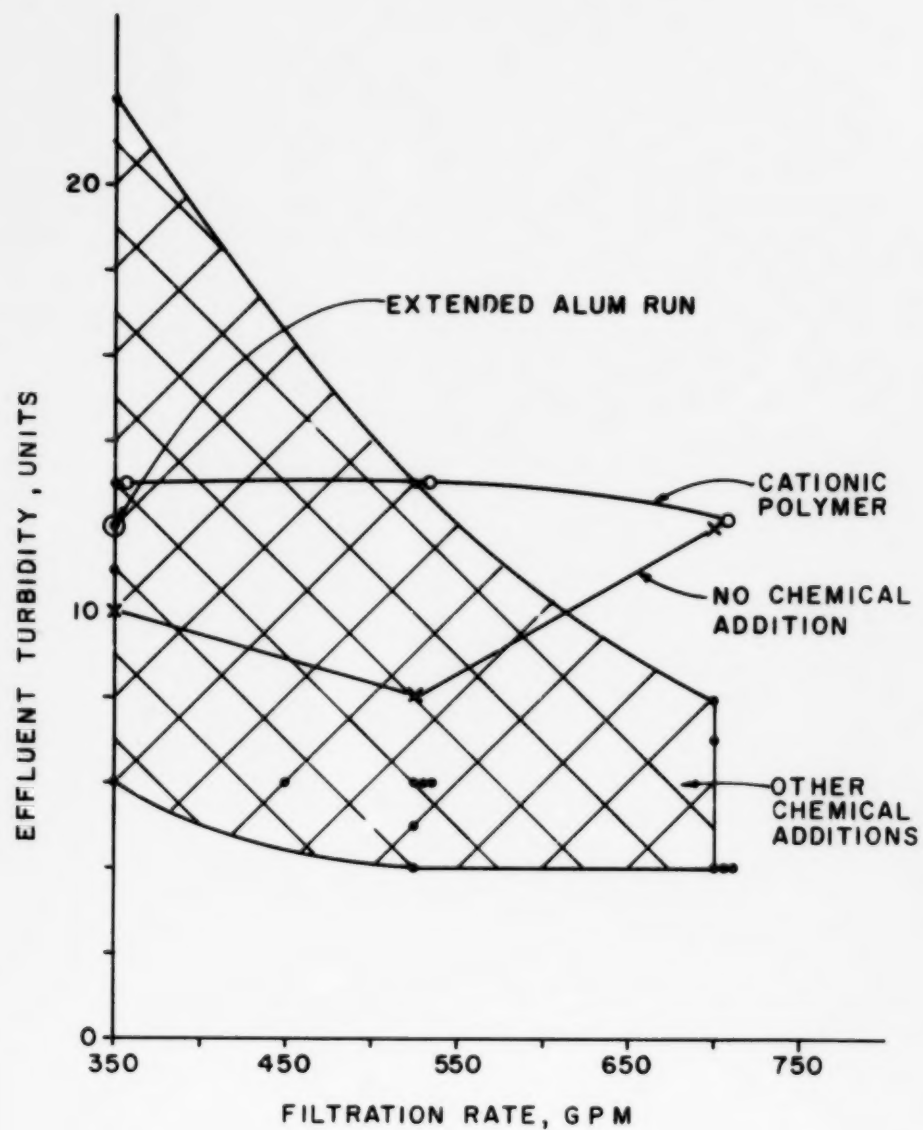


FIGURE 10 EFFECTS OF CHEMICAL ADDITION AND FILTRATION RATE ON EFFLUENT TURBIDITY

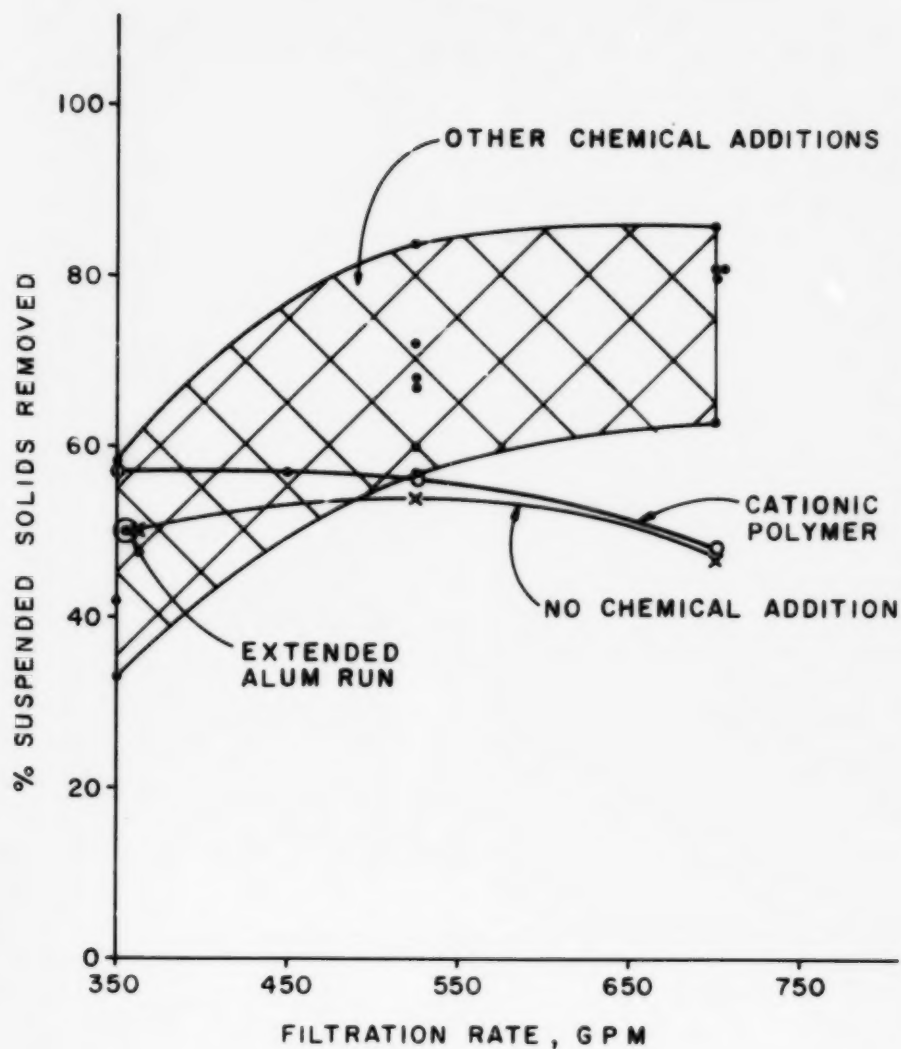


FIGURE II EFFECTS OF CHEMICAL ADDITION AND FILTRATION RATE ON SUSPENDED SOLIDS REMOVAL

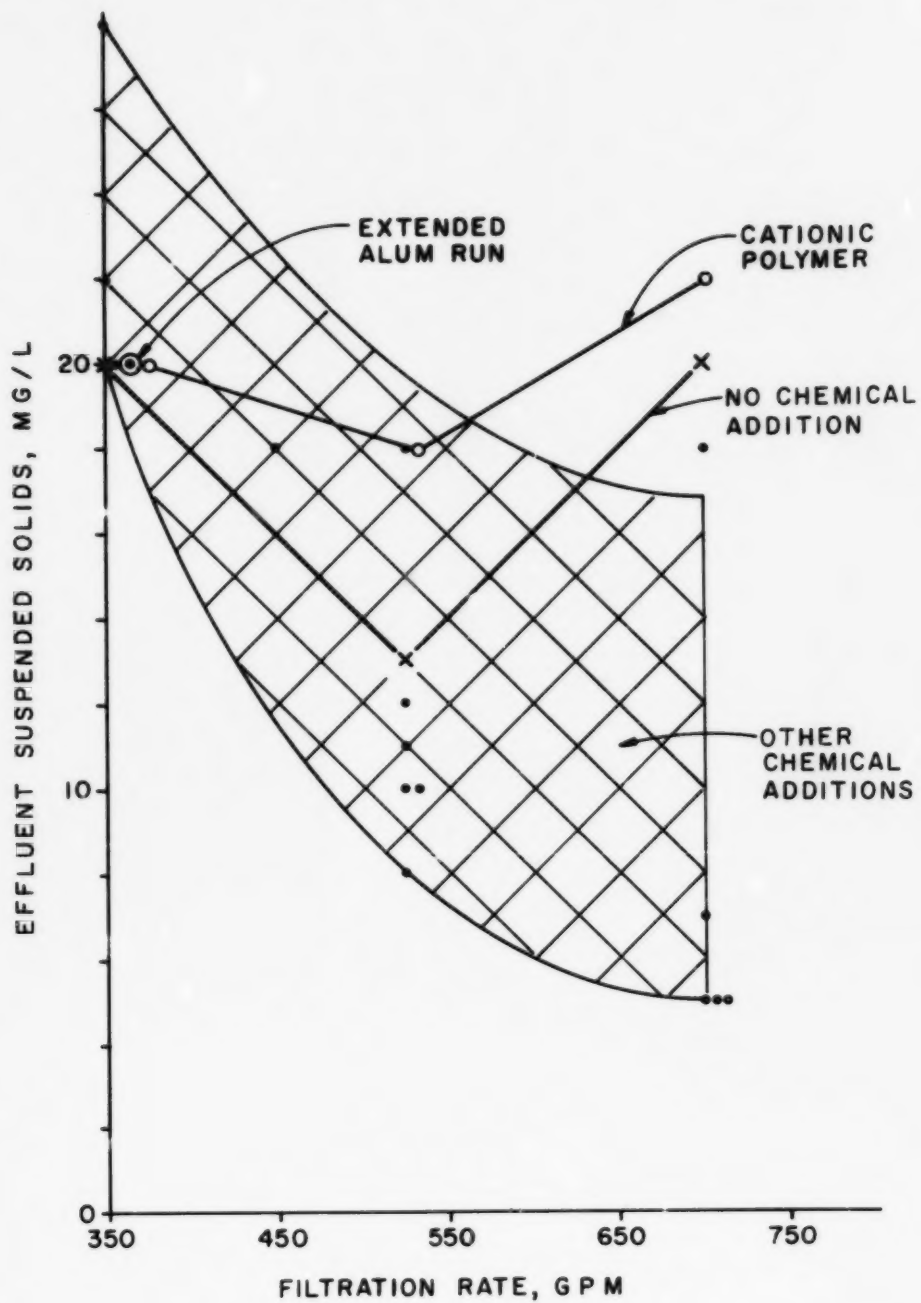


FIGURE 12 EFFECTS OF CHEMICAL ADDITION AND FILTRATION RATE ON EFFLUENT SUSPENDED SOLIDS

Figures 11 and 12 show the effect of chemical addition on suspended solids removal. As with turbidity, suspended solids removal was most efficient at the highest filtration rate provided that chemicals were added. There appeared to be little benefit from use of chemicals to enhance solids removal at the lowest filtration rate.

The decision was reached to proceed into the full-scale test program on the basis of a water flow rate of 350 GPM and to use alum alone as the coagulant. It was also decided that the effluent turbidity criterion of 5 JTU established initially for filter performance would be relaxed whenever it became apparent that alum input required to achieve this level of clarity would seriously curtail the filter cycle.

Appendix B lists data developed for Runs 62 through 95, which comprised the final test phase. From these data, influent turbidities and suspended solids were plotted in Figure 13 to show the weekly variation over the seven-week period. The parallel relationship between the two variables was consistent within any given week, both tending to begin the week at a relatively low level and, generally, to rise as the week progressed. A probable influence on the low levels of turbidity and suspended solids at the beginning of each week and the progressive increases in their values was the contribution of waste discharges to the sewage collection system from the many industrial plants, which operate during the week and are idle over the week-end. A notable exception to this general rising tendency appears at the end of week number 4 in May. It was on this day that the only rainfall of sufficient intensity to dilute the incoming sewage occurred during the entire seven-week period of the final test phase.

Weekly plots of influent BOD₅ and COD values appear in Figure 14. A consistent relationship between the two variables could not be detected.

Figure 15 includes weekly plots of influent total phosphate and orthophosphate and shows a very definite parallel relationship between the two. Also detectable is the generally slight variation in values over the entire period, with the notable exceptions of higher readings in the first week, and, again, as in the case of the turbidity and

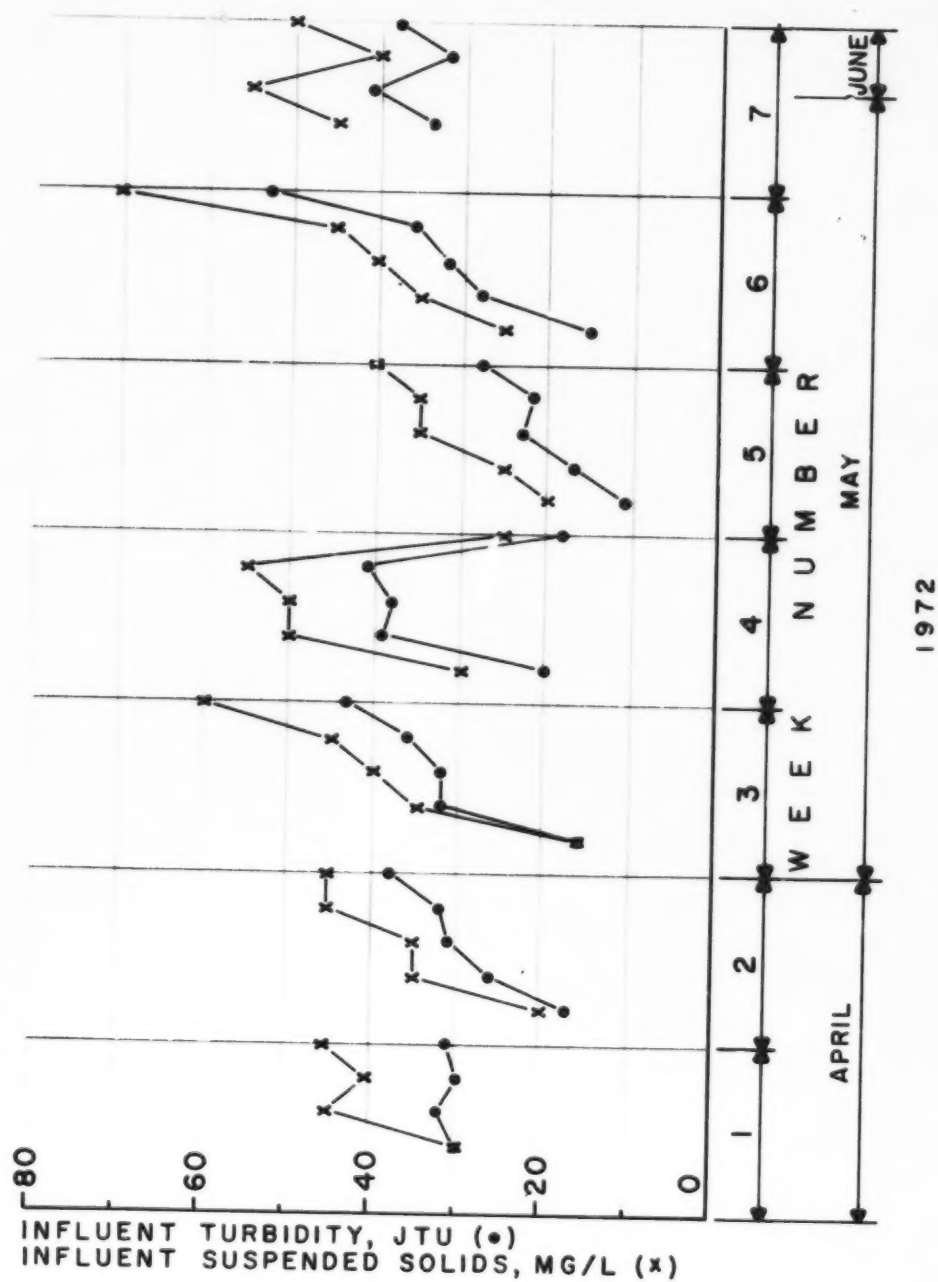


FIGURE 13 FINAL TEST STAGE
WEEKLY VARIATION IN INFLUENT
TURBIDITY AND SUSPENDED SOLIDS

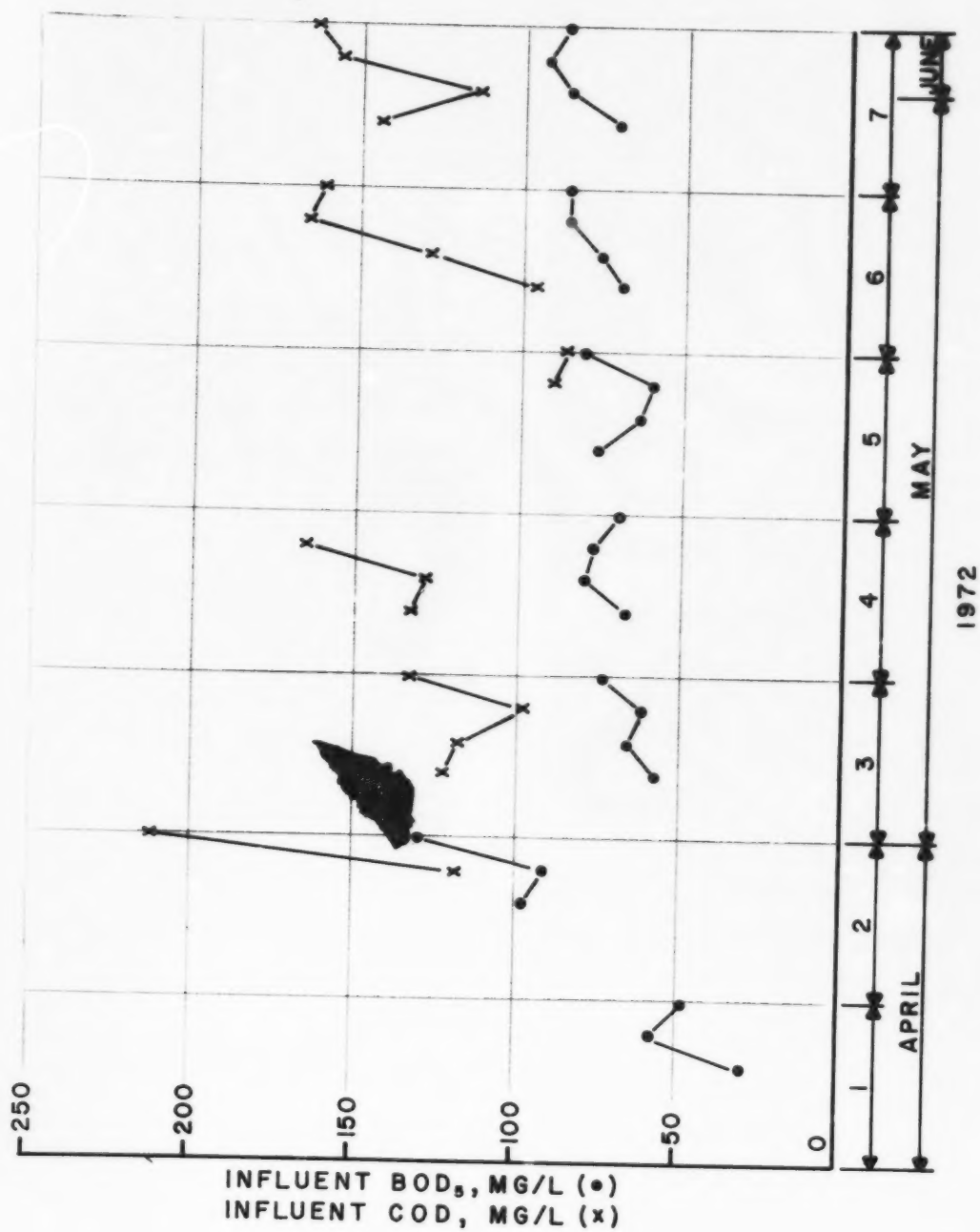


FIGURE 14 FINAL TEST STAGE WEEKLY
VARIATION IN INFLUENT BOD₅ & COD

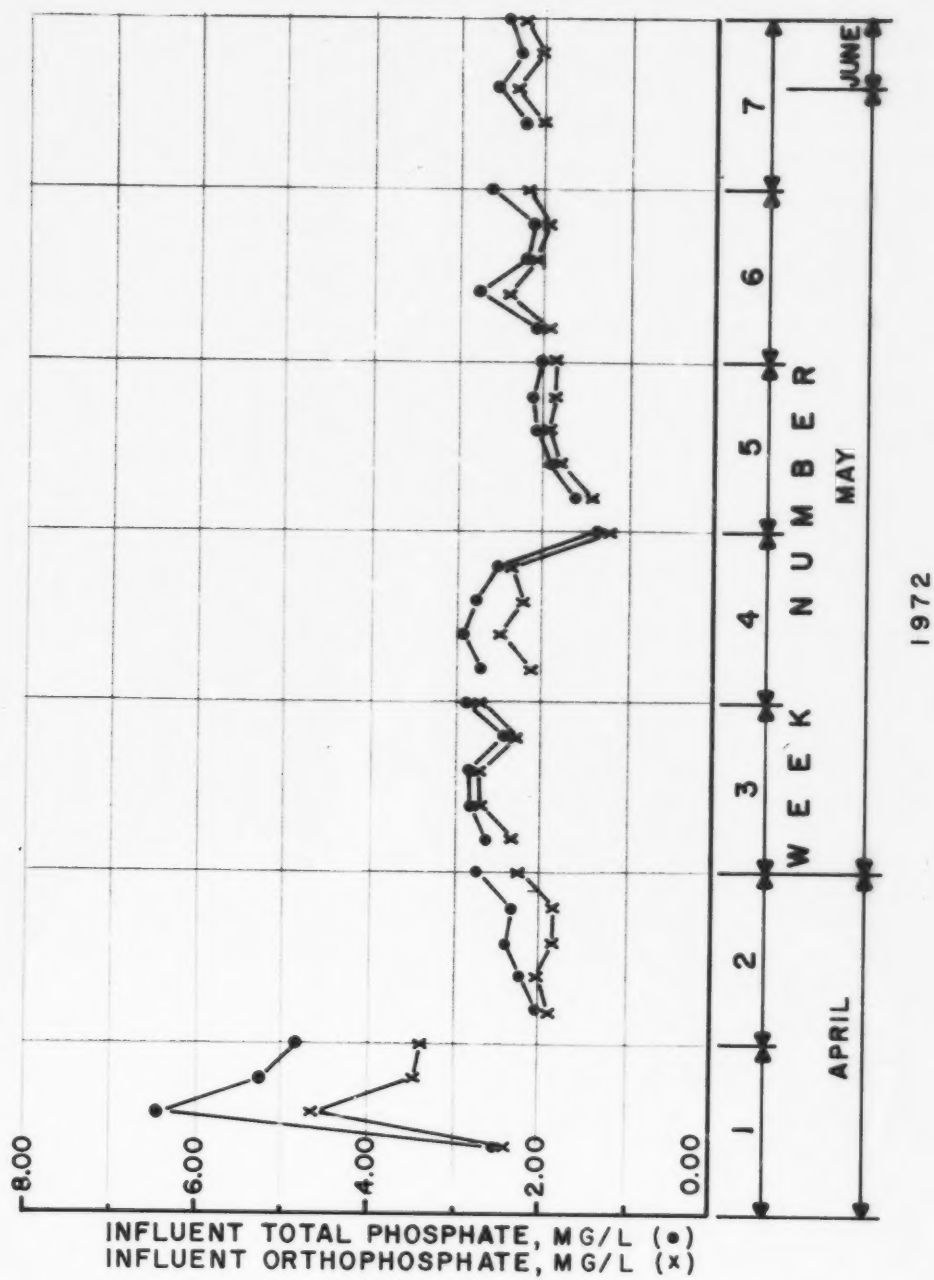


FIGURE 15 FINAL TEST STAGE WEEKLY
VARIATION IN INFLUENT PHOSPHATES

suspended solids, a precipitous plunge at the end of the fourth week -- no doubt attributable to the dilution resulting from heavy rainfall. Notable, too, is the close proximity between the two curves, showing that the orthophosphate was the major contributor to the total phosphate concentration. This wastewater contained much less phosphate than typical domestic wastewater.

The weekly variation in influent pH appears in Figure 16. No pattern of consistency or change, either within any week or over the entire period, is apparent.

During the final test phase the longest run, number 81, lasted 6-1/2 hours. This was the first test day after the only occurrence of rainfall and the resultant influent sewage dilution. Influent turbidity was the lowest, at 11 JTU, over the seven-week period; also, influent suspended solids level was the lowest at 20 mg/l -- matched only by Run 66. Figure 17 is a plot of turbidity values in JTU for filter effluent with respect to influent, with a linear curve superimposed to indicate the relationship between these two variables, based on least-square method, between influent turbidity values of 11 and 53 as recorded during the study.

The highest filter pressure buildup, 2.1 pounds per square inch, was logged for the last run, number 95, and all final-test-phase runs were terminated by solids breakthrough accompanied by a drop in the pressure gauge reading at the filter inlet.

Effluent suspended solids values down to 5 mg/l were reached for Runs 71, 81, 82 and 83 -- results for the latter three attributable to the aftereffects of the heavy rainfall occurring on the day of Run 80.

Effluent turbidity values were dropped to 5 JTU and lower only for Run 66 and for Runs 80 through 83 -- again under the dilution influence caused by the rain. Values of effluent suspended solids with respect to influent suspended solids, in mg/l, have been plotted on Figure 18 and the superimposed linear curve for these two variables indicates their relationship, based on least-square method, between influent values of 20 and 70 mg/l.

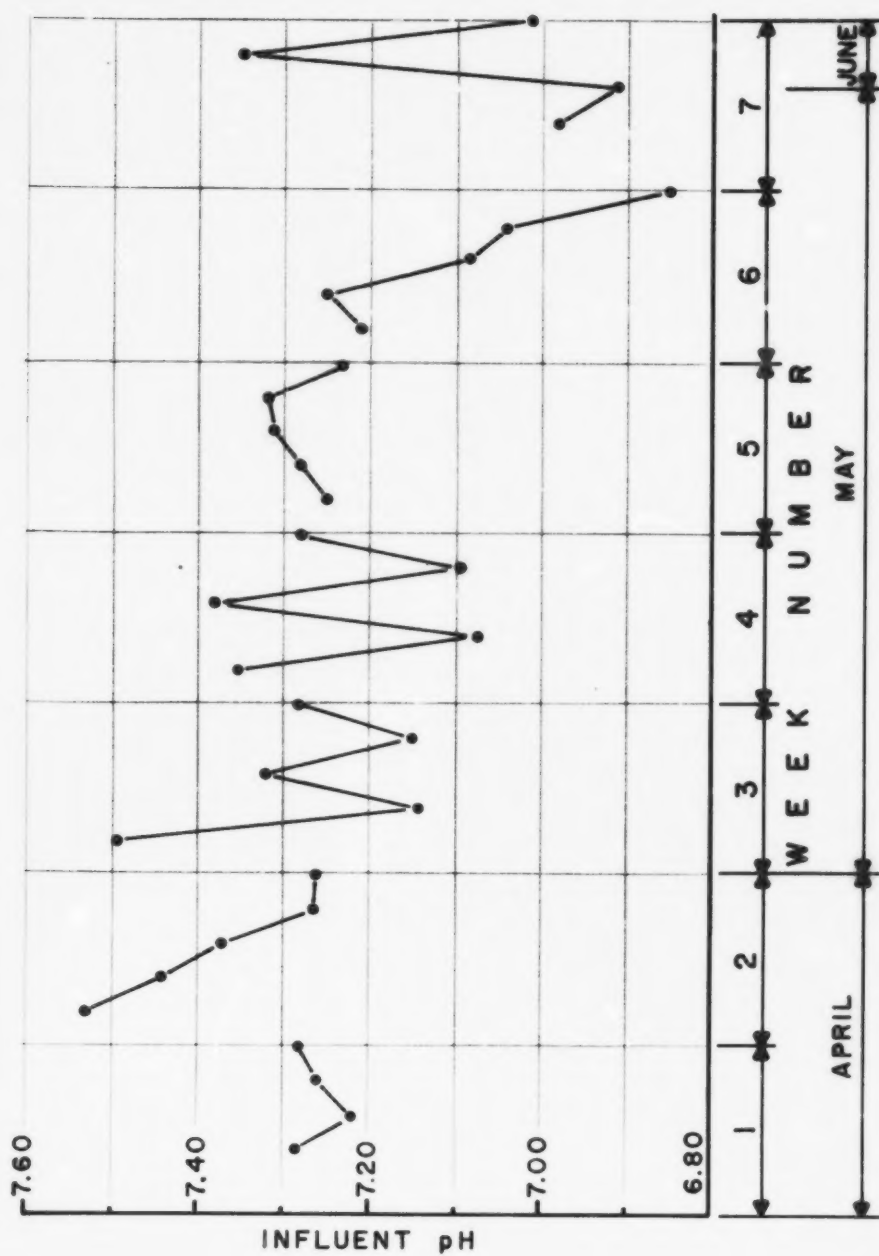


FIGURE 16 FINAL TEST STAGE WEEKLY VARIATION IN INFLUENT pH

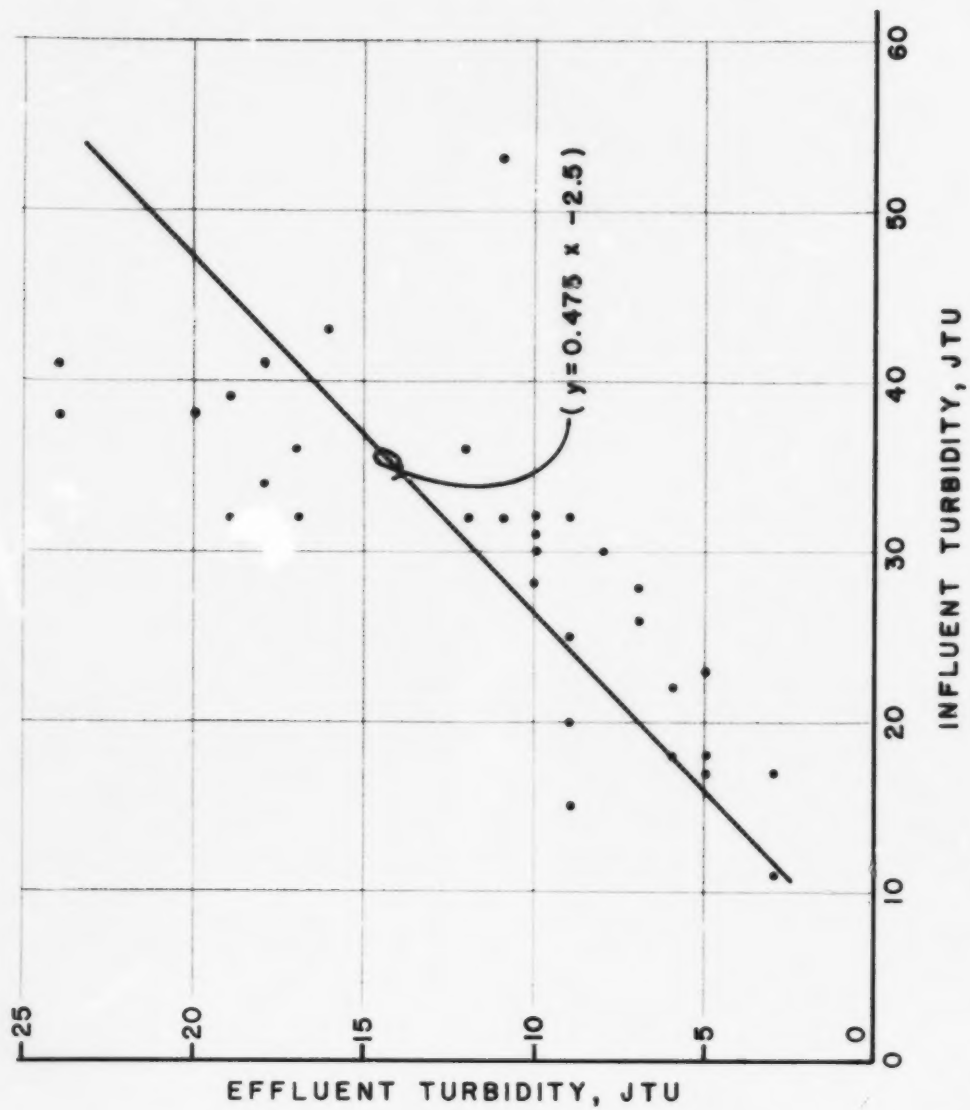


FIGURE 17 FINAL TEST STAGE EFFLUENT
TURBIDITY VS INFLUENT TURBIDITY

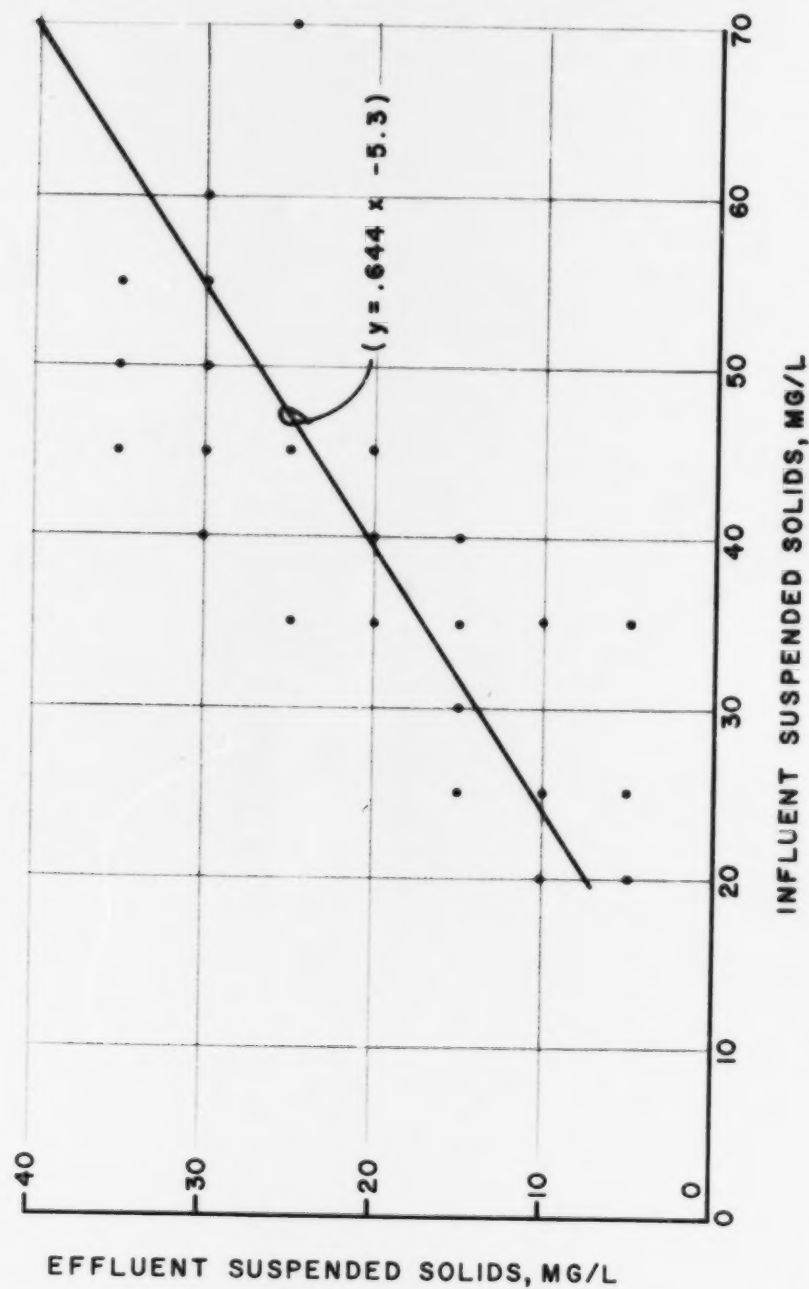


FIGURE 18 FINAL TEST STAGE EFFLUENT
SUSPENDED SOLIDS VS
INFLUENT SUSPENDED SOLIDS

The general tendency noted earlier for the influent turbidity values to rise from the beginning to the end of a week was accompanied by parallel alum input demands. As alum input rose, the effectiveness of the alum on per cent reduction in turbidity tended to rise to a peak and then decrease, as indicated by Figure 19, in which average per cent reduction in turbidity has been plotted against alum input in mg/l. The resulting curve shows a peak effectiveness for this operation at approximately 80 mg/l.

Near the end of Run 95 on the last day of plant operation alum was injected at the rate of 650 mg/l for a 15-minute period. With this massive dose, the effluent turbidity dropped no lower than 5 JTU and was maintained for less than 30 minutes, at which point breakthrough occurred.

Effluent BOD₅ and COD values developed no definite pattern either alone or with respect to each other or to any of the other effluent variables, nor did the BOD₅ or COD reduction exhibit any such relationship. Effluent BOD₅ ranged from a low value of 18 mg/l (Run 63) to a high of 110 mg/l (Run 70), averaging 46 mg/l for the series. Run 72 had the highest percent BOD₅ reduction at 62; the lowest was 15 per cent for Run 70; average percent reduction was 39. Lowest effluent COD was recorded for Run 91 at 39 mg/l; highest for Run 95 at 121; average, 77 mg/l. In percent COD reduction, the lowest value was 15, for Run 70; the highest was 76, for Run 91; average, 41 per cent.

Effectiveness in reduction of total phosphate and orthophosphate peaked simultaneously in the period immediately following the heavy rains that occurred during Run 80. Highest per cent reduction for both parameters was 47 (Run 82); next highest was 38 per cent for total phosphate and 36 per cent for orthophosphate (Run 81 in both cases). Average per cent reduction was 21 for total phosphate and 23 per cent for orthophosphate.

Effluent pH values were all lower than the corresponding influent readings, reflecting the influence of the alum injection into the influent waste water.

Average values of operating conditions and analytical measurements for Runs 62 - 95 are recorded in Appendix B. Pertinent points are also recorded in Figures 8 - 12 for comparison with the preliminary test operations.

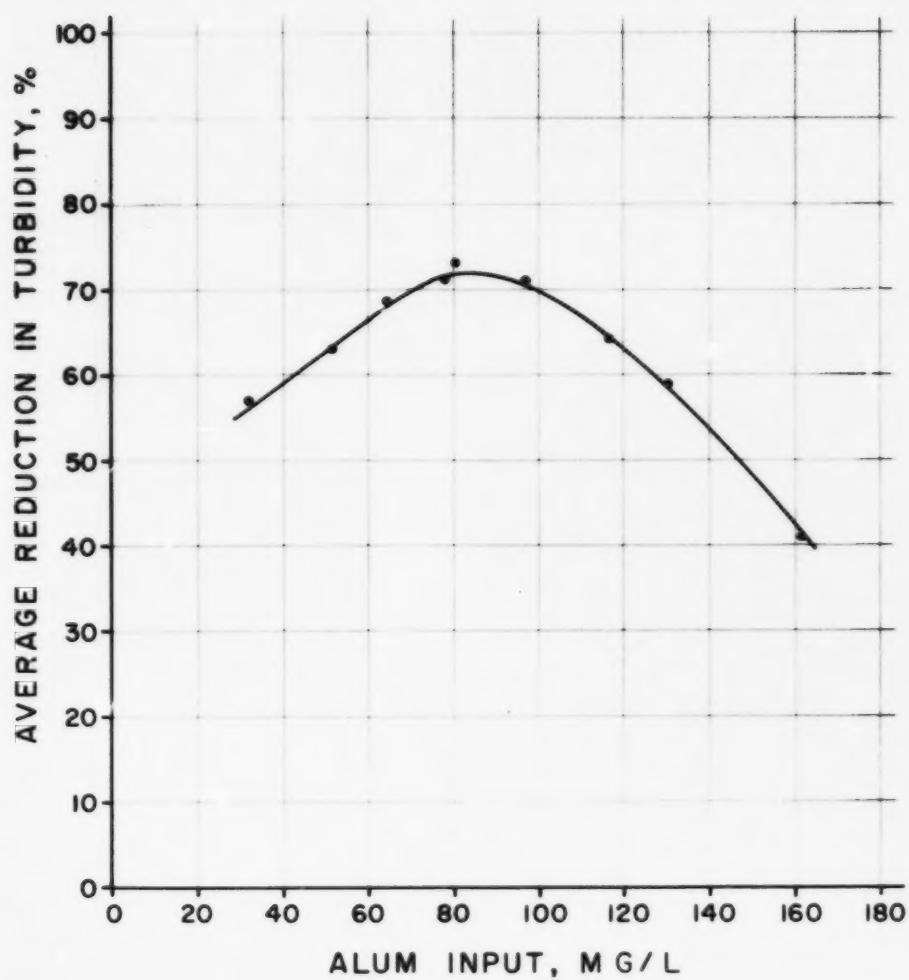


FIGURE 19 TURBIDITY REDUCTION WITH
RESPECT TO ALUM INPUT

It was observed that during the seven-week final test phase the odor associated with hydrogen sulfide became progressively more prominent at the treatment plant. This odor was not apparent during the early stages of the preliminary test phase and first appeared, to an offensively noticeable degree, late in March, 1972, two or three weeks before the conclusion of preliminary testing. Coincidental with this occurrence was the gradual increase in atmospheric dry bulb temperatures and the almost total absence of rainfall during the same period.

The upflow filter plant was operated at a flow rate of 0.5 millions gallons per day to satisfy the prevailing conditions of the installation and the waste water that was being filtered. The installation was of a semi-permanent, low-cost nature. The estimate of cost for a permanent 0.5 MGD upflow filter plant for the same waste water is \$91,500, as shown in Table I. This is the estimated cost for a single-filter plant, with no backup facility for continuous waste water filtration for that portion of the time -- approximately forty-five minutes for each complete cycle -- required for the flushing operation. To install such a backup facility, which would include a second filter, pump, piping and other auxiliary elements, would add approximately \$45,000 to the construction cost. Amortization of capital costs for a single-filter plant at 6 percent interest and 25 years is \$7150/year, while addition of a second filter would increase the annual amortization to \$10,671/year.

TABLE I
PLANT INSTALLATION COSTS (0.5 MGD)

Equipment (Filter, Pumps, Blower Compressor, Chemical Apparatus)	\$53,000
Bases and Foundations	5,400
Piping and Valves	11,700
Instrumentation and Controls	8,800
Electrical	<u>12,500</u>
Total	\$91,400

For 1 Filter:

Amortize \$91,400 @ 6% and 25 years - \$ 7,150/year

For 2 Filters:

Amortize \$136,400 @ 6% and 25 years - \$10,671/year

The estimated annual cost of operating such a plant is \$25,700, as shown in Table 2. Operation at a nominal 0.5 MGD rate would filter 182.5 million gallons of wastewater per year. Total operating costs are therefore \$0.18/1000 gallons for one filter and \$0.20/1000 gallons for two filters. Operation without chemical addition would be considerably less expensive but with lower efficiency of solids removal.

TABLE 2
ANNUAL OPERATING COSTS (0.5 MGD)

Power	\$ 3,520
Water	130
Chemicals	4,750
Maintenance and Repair	4,750
Labor	<u>12,550</u>
Operating Cost	\$25,700

For Intermittent Filtration with 1 Filter:

Total Annual Cost = \$25,700 + 7,150 = \$32,850

Total Operating Cost:

$$\frac{\$32,850}{182,500 \times 1000 \text{ gal.}} = \$0.18/1000 \text{ gal.}$$

For Continuous Filtration with 2 Filters:

Total Annual Cost = \$25,700 + \$10,671 = \$36,371

Total Operating Cost:

$$\frac{\$36,371}{182,500 \times 1000 \text{ gal.}} = \$0.20/1000 \text{ gal.}$$

SECTION VII

ACKNOWLEDGEMENTS

Sincere appreciation is extended to Mr. C. L. Swanson, who was the Environmental Protection Agency Project Officer during the development stages of this project, and to the succeeding Project Officers, Dr. Sidney A. Hannah and Mr. Gerald Stern, who also provided excellent guidance and cooperation.

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SECTION VIII

APPENDICES

	<u>PAGE NO.</u>
A. Preliminary Phase Operational Data	46
B. Final Phase Operational Data	57

APPENDIX A
PRELIMINARY PHASE OPERATIONAL DATA

Run No.	1	2	3	4	5	6
Duration, Hours	30	18	19	47	21	17
Flow, GPM	350	350	525	350	525	525
1000 Gallons Filtered	630	378	598	987	662	536
Filter Pressure Rise, PSI	2.0	1.4	1.5	4.8	3.6	2.4
Sample Temperature, F	74	71	72	72	67	68
Alum Input, mg/l	--	--	--	--	--	--
Polymer:						
Type	--	--	--	--	--	--
Input, mg/l	--	--	--	--	--	--
Turbidity, JTU:						
Influent	31	19	18	17	16	18
Effluent	13	7	9	9	7	7
% Change	58	63	50	47	56	61
Suspended Solids, mg/l:						
Influent	--	40	25	40	30	--
Effluent	--	20	15	20	10	--
% Change	--	50	40	50	67	--
pH:						
Influent	--	7.32	7.65	7.79	7.61	--
Effluent	--	7.49	7.65	7.80	7.61	--

APPENDIX A
PRELIMINARY PHASE OPERATIONAL DATA
(CONT'D)

Run No.	7	8	9	10	11	12
Duration, Hours	28	24	18	6	5	21
Flow, GPM	700	700	700	450	450	350
1000 Gallons Filtered	1,176	1,008	756	162	135	441
Filter Pressure Rise, PSI	4.4	3.9	2.2	1.9	1.9	6.9
Sample Temperature, F	71	70	72	68	70	68
Alum Input, mg/l	--	--	--	80	8	6
Polymer:						
Type	--	--	--	--	--	--
Input, mg/l	--	--	--	--	--	--
Turbidity, JTU:						
Influent	19	18	23	23	18	22
Effluent	11	11	13	8	4	6
% Change	42	39	43	65	78	73
Suspended Solids, mg/l:						
Influent	35	30	50	50	35	40
Effluent	20	15	25	25	10	20
% Change	43	50	50	50	71	50
pH:						
Influent	7.20	7.36	7.50	7.33	7.28	7.22
Effluent	7.21	7.42	7.50	7.41	7.35	7.25

APPENDIX A
PRELIMINARY PHASE OPERATIONAL DATA
(CONT'D)

Run No.	13	14	15	16	17	18
Duration, Hours	6.0	6.5	6.5	17.5	6.5	7.0
Flow, GPM	525	525	525	700	700	700
1000 Gallons Filtered	189	205	205	735	273	294
Filter Pressure Rise, PSI	1.6	1.6	2.6	3.2	1.8	2.0
Sample Temperature, F	71	68	69	70	63	64
Alum Input, mg/l	9	10	15	16	16	9
Polymer:						
Type	--	--	--	--	--	--
Input, mg/l	--	--	--	--	--	--
Turbidity, JTU:						
Influent	20	15	24	18	16	17
Effluent	5	8	5	3	2	4
% Change	75	47	79	83	88	76
Suspended Solids, mg/l:						
Influent	40	30	50	35	40	25
Effluent	10	10	10	5	5	5
% Change	75	67	80	86	87	80
pH:						
Influent	7.50	7.53	7.26	7.35	7.61	7.49
Effluent	7.49	7.53	7.28	7.38	7.62	7.39

APPENDIX A

PRELIMINARY PHASE OPERATIONAL DATA (CONT'D)

Run No.	19	20	21	22	23	24
Duration, Hours	5.5	7.0	6.5	7.0	8.0	8.0
Flow, GPM	350	350	350	525	525	525
1000 Gallons Filtered	116	147	136	220	252	252
Filter Pressure Rise, PSI	0.4	0.4	0.5	0.6	0.5	1.0
Sample Temperature, F	65	65	66	67	64	64
Alum Input, mg/l	--	--	--	--	--	--
Polymer:						
Type (l)	LO-C	LO-C	LO-C	LO-C	LO-C	LO-C
Input, mg/l	8	20	19	10	19	9
Turbidity, JTU:						
Influent	27	29	26	27	26	26
Effluent	10	13	12	15	14	9
% Change	63	55	54	44	46	65
Suspended Solids, mg/l:						
Influent	45	45	50	45	35	45
Effluent	10	20	20	25	15	15
% Change	78	56	60	44	57	67
pH:						
Influent	7.47	7.55	7.45	7.42	7.51	7.26
Effluent	7.47	7.50	7.37	7.31	7.47	7.22

APPENDIX A

PRELIMINARY PHASE OPERATIONAL DATA (CONT'D)

Run No.	25	26	27	28	29	30
Duration, Hours	21.0	8.0	8.0	9.5	8.0	7.5
Flow, GPM	700	700	350	350	350	525
1000 Gallons Filtered	882	336	168	200	168	236
Filter Pressure Rise, PSI	6.8	1.2	0.5	0.9	1.2	2.1
Sample Temperature, F	65	67	69	68	70	70
Alum Input, mg/l	--	--	4	6	16	19
Polymer:						
Type (1)	L0-C	L0-C	L0-C	L0-C	--	--
Input, mg/l	3	7	2	2	--	--
Turbidity, JTU:						
Influent	22	21	30	32	28	26
Effluent	10	14	20	24	10	6
% Change	55	33	33	25	64	77
Suspended Solids, mg/l:						
Influent	40	45	40	45	50	45
Effluent	15	30	25	30	20	15
% Change	62	33	37	33	60	67
pH:						
Influent	7.32	7.36	7.24	7.04	7.22	7.13
Effluent	7.21	7.28	7.02	7.00	7.21	7.15

APPENDIX A
PRELIMINARY PHASE OPERATIONAL DATA
(CONT'D)

Run No.	31	32	33	34	35	36
Duration, Hours	8.0	5.5	5.0	4.5	4.5	4.0
Flow, GPM	525	525	700	700	700	525
1000 Gallons Filtered	252	173	210	189	189	126
Filter Pressure Rise, PSI	3.6	0.9	1.6	1.1	1.8	2.1
Sample Temperature, F	69	68	67	67	69	65
Alum Input, mg/l	19	19	19	19	16	19
Polymer:						
Type (I)	L0-C	L0-C	L0-C	L0-C	L0-C	L0-C
Input, mg/l	6	1	4	6	7	6
Turbidity, JTU:						
Influent	29	23	26	22	27	21
Effluent	5	5	8	5	7	4
% Change	83	78	69	77	74	81
Suspended Solids, mg/l:						
Influent	65	45	55	40	50	40
Effluent	10	10	30	5	20	5
% Change	85	78	45	87	60	87
pH:						
Influent	7.28	7.39	7.46	7.29	7.22	7.39
Effluent	7.20	7.42	7.51	7.30	7.22	7.39

APPENDIX A
PRELIMINARY PHASE OPERATIONAL DATA
(CONT'D)

Run No.	37	38	39	40	41	42
Duration, Hours	5.5	4.5	8.0	7.0	4.0	4.0
Flow, GPM	700	700	350	700	700	700
1000 Gallons Filtered	231	189	168	294	168	168
Filter Pressure Rise, PSI	1.8	1.8	0.5	1.1	1.8	1.1
Sample Temperature, F	70	70	71	68	68	68
Alum Input, mg/l	6	13	--	13	13	13
Polymer:						
Type (1)	HI-C	--	LO-C	--	HI-C	HI-C
Input, mg/l	0.5	--	6	--	0.1	0.3
Turbidity, JTU:						
Influent	--	21	29	23	12	24
Effluent	--	4	18	8	4	4
% Change	--	81	38	65	67	83
Suspended Solids, mg/l:						
Influent	--	45	50	40	20	40
Effluent	--	5	30	15	5	5
% Change	--	89	40	62	75	87
pH:						
Influent	--	7.35	7.38	7.23	7.36	7.28
Effluent	--	7.41	7.42	7.30	7.30	7.25

APPENDIX A

PRELIMINARY PHASE OPERATIONAL DATA (CONT'D)

Run No.	43	44	45	46	47	48
Duration, Hours	9.0	4.0	6.5	5.5	4.0	5.5
Flow, GPM	350	700	525	525	700	700
1000 Gallons Filtered	189	168	205	173	168	231
Filter Pressure Rise, PSI	1.8	1.6	1.6	1.9	1.4	1.5
Sample Temperature, F	68	68	69	70	70	73
Alum Input, mg/l	13	13	13	16	13	19
Polymer:						
Type (I)	HI-C	HI-C	HI-C	HI-C	HI-A	HI-A
Input, mg/l	0.2	0.5	0.7	0.05	0.1	0.2
Turbidity, JTU:						
Influent	25	14	19	16	13	17
Effluent	6	3	4	5	4	3
% Change	76	79	79	69	69	82
Suspended Solids, mg/l:						
Influent	--	20	40	20	20	25
Effluent	--	5	15	5	5	5
% Change	--	75	62	75	75	80
pH:						
Influent	--	7.55	7.26	7.23	7.47	7.36
Effluent	--	7.52	7.23	7.23	7.44	7.33

APPENDIX A

PRELIMINARY PHASE OPERATIONAL DATA (CONT'D)

Run No.	49	50	51	52	53	54
Duration, Hours	3.0	2.0	2.0	5.0	2.5	2.5
Flow, GPM	700	700	700	525	525	525
1000 Gallons Filtered	126	84	84	158	79	79
Filter Pressure Rise, PSI	1.5	1.2	0.8	1.9	1.2	1.2
Sample Temperature, F	72	68	69	71	72	72
Alum Input, mg/l	26	26	29	16	32	32
Polymer:						
Type (I)	HI-A	HI-N	HI-N	HI-N	HI-N	HI-A
Input, mg/l	0.1	0.05	0.1	0.05	0.2	0.5
Turbidity, JTU:						
Influent	20	22	35	14	28	24
Effluent	4	4	12	5	8	5
% Change	80	82	66	64	71	79
Suspended Solids, mg/l:						
Influent	30	35	--	25	--	45
Effluent	5	5	--	10	--	10
% Change	83	86	--	60	--	78
pH:						
Influent	7.31	7.46	--	7.65	--	7.21
Effluent	7.22	7.36	--	7.62	--	7.09

APPENDIX A

PRELIMINARY PHASE OPERATIONAL DATA (CONT'D)

Run No.	55	56	57	58	59	60
Duration, Hours	3.5	2.5	4.0	4.0	4.5	3.5
Flow, GPM	525	525	525	525	350	350
1000 Gallons Filtered	110	79	126	126	94	74
Filter Pressure Rise, PSI	2.0	1.5	1.8	1.8	1.8	1.9
Sample Temperature, F	71	72	72	74	75	75
Alum Input, mg/l	65	65	31	39	84	97
Polymer:						
Type (1)	HI-A	HI-A	--	--	--	--
Input, mg/l	1.5	2.0	--	--	--	--
Turbidity, JTU:						
Influent	20	35	18	31	42	32
Effluent	4	10	6	8	9	18
% Change	80	71	67	74	79	44
Suspended Solids, mg/l:						
Influent	30	--	30	--	--	35
Effluent	15	--	10	--	--	25
% Change	50	--	67	--	--	29
pH:						
Influent	7.32	--	7.42	--	--	7.41
Effluent	7.27	--	7.36	--	--	7.38

APPENDIX A

PRELIMINARY PHASE OPERATIONAL DATA (CONT'D)

Run No.	61
Duration, Hours	4.5
Flow, GPM	525
1000 Gallons Filtered	142
Filter Pressure Rise, PSI	1.8
Sample Temperature, F	73
Alum Input, mg/l	19
Polymer:	
Type	--
Input, mg/l	--
Turbidity, JTU	
Influent	15
Effluent	5
% Change	67
Suspended Solids, mg/l:	
Influent	--
Effluent	--
% Change	--
pH:	
Influent	--
Effluent	--

Notes: (1) LO-C: Low-molecular-weight cationic
 HI-C: High-molecular-weight cationic
 HI-A: High-molecular-weight anionic
 HI-N: High-molecular-weight non-ionic

APPENDIX B
FINAL PHASE OPERATIONAL DATA

Run No.	62	63	64	65	66	67
Duration, Hours	3.5	3.5	3.5	2.5	4.5	3.0
Flow, GPM	350	350	350	350	350	350
1000 Gallons Filtered	74	74	74	52	94	63
Filter Pressure Rise, PSI	1.9	1.6	1.6	1.9	2.0	1.8
Sample Temperature, F	75	75	76	76	75	74
Alum Input, mg/l	78	78	97	117	32	97
Turbidity, JTU:						
Influent	30	32	30	31	17	26
Effluent	8	10	10	10	5	7
% Change	73	69	67	68	71	73
Suspended Solids, mg/l:						
Influent	30	45	40	45	20	35
Effluent	15	20	20	20	10	10
% Change	50	56	50	56	50	71
BOD ₅ , mg/l:						
Influent	--	30	58	48	--	--
Effluent	--	18	30	26	--	--
% Change	--	40	48	46	--	--
COD, mg/l:						
Influent	--	--	--	--	--	--
Effluent	--	--	--	--	--	--
% Change	--	--	--	--	--	--
Total Phosphate, mg/l P:						
Influent	2.50	6.40	5.20	4.80	2.00	2.20
Effluent	2.00	6.00	4.70	4.20	1.72	2.00
% Change	20	6	10	12	14	9
Orthophosphate, mg/l P:						
Influent	2.40	4.60	3.40	3.35	1.88	2.00
Effluent	1.80	4.10	3.10	3.00	1.60	1.60
% Change	25	11	9	10	15	20
pH:						
Influent	7.28	7.22	7.26	7.28	7.53	7.44
Effluent	7.20	7.16	7.20	7.20	7.39	7.19

APPENDIX B
FINAL PHASE OPERATIONAL DATA
(CONT'D)

Run No.	68	69	70	71	72	73
Duration, Hours	3.0	3.0	2.5	4.5	3.0	3.5
Flow, GPM	350	350	350	350	350	350
1000 Gallons Filtered	63	63	52	94	63	74
Filter Pressure Rise, PSI	1.9	1.8	1.8	1.4	1.8	1.8
Sample Temperature, F	73	74	74	75	76	75
Alum Input, mg/l	97	130	130	52	97	130
Turbidity, JTU:						
Influent	31	32	38	18	32	32
Effluent	10	12	20	6	11	17
% Change	68	62	47	67	66	47
Suspended Solids, mg/l:						
Influent	35	45	45	20	35	40
Effluent	20	25	35	5	25	30
% Change	43	44	22	75	29	25
BOD ₅ , mg/l:						
Influent	98	92	130	--	58	66
Effluent	68	65	110	--	22	32
% Change	31	29	15	--	62	52
COD, mg/l:						
Influent	--	118	212	--	122	118
Effluent	--	55	180	--	43	47
% Change	--	53	15	--	65	60
Total Phosphate, mg/l P:						
Influent	2.40	2.30	2.70	2.60	2.80	2.80
Effluent	2.00	1.90	2.15	2.10	2.10	2.20
% Change	17	17	20	19	25	21
Orthophosphate, mg/l P:						
Influent	1.80	1.80	2.20	2.30	2.70	2.75
Effluent	1.40	1.40	1.60	2.00	2.00	2.10
% Change	22	22	27	13	26	24
pH:						
Influent	7.37	7.26	7.26	7.49	7.14	7.32
Effluent	7.05	6.85	6.90	7.23	6.87	6.90

APPENDIX B
FINAL PHASE OPERATIONAL DATA
(CONT'D)

Run No.	74	75	76	77	78	79
Duration, Hours	3.0	3.0	4.5	3.0	3.0	3.0
Flow, GPM	350	350	350	350	350	350
1000 Gallons Filtered	63	63	94	63	63	63
Filter Pressure Rise, PSI	1.6	1.8	1.9	1.6	1.6	1.8
Sample Temperature, F	75	75	76	76	76	76
Alum Input, mg/l	130	130	52	130	130	130
Turbidity, JTU:						
Influent	36	43	20	39	38	41
Effluent	12	16	9	19	20	18
% Change	67	63	55	51	47	56
Suspended Solids, mg/l:						
Influent	45	60	30	50	50	55
Effluent	25	30	15	30	30	30
% Change	44	50	50	40	40	45
BOD ₅ , mg/l:						
Influent	62	74	--	68	80	78
Effluent	32	36	--	28	44	52
% Change	48	51	--	59	45	33
COD, mg/l:						
Influent	98	133	--	133	129	165
Effluent	41	55	--	67	94	102
% Change	58	59	--	50	27	38
Total Phosphate, mg/l P:						
Influent	2.40	2.85	2.70	2.90	2.75	2.50
Effluent	1.85	2.30	1.85	2.40	2.00	1.90
% Change	23	19	31	17	27	24
Orthophosphate, mg/l P:						
Influent	2.25	2.70	2.10	2.45	2.20	2.35
Effluent	1.70	2.05	1.60	2.00	1.65	1.80
% Change	24	24	24	18	25	23
pH:						
Influent	7.15	7.28	7.35	7.07	7.38	7.09
Effluent	6.81	6.93	7.19	6.74	7.02	6.92

APPENDIX B

FINAL PHASE OPERATIONAL DATA (CONT'D)

Run No.	80	81	82	83	84	85
Duration, Hours	4.0	6.5	3.5	4.0	4.5	3.5
Flow, GPM	350	350	350	350	350	350
1000 Gallons Filtered	84	136	74	84	94	74
Filter Pressure Rise, PSI	1.5	1.9	1.6	1.6	1.6	1.9
Sample Temperature, F	74	74	75	75	75	76
Alum Input, mg/l	52	32	81	81	65	65
Turbidity, JTU:						
Influent	18	11	17	23	22	28
Effluent	5	3	3	5	6	10
% Change	72	73	82	78	73	64
Suspended Solids, mg/l:						
Influent	25	20	25	35	35	40
Effluent	10	5	5	5	10	15
% Change	60	75	80	86	71	62
BOD ₅ , mg/l:						
Influent	70	--	76	64	60	81
Effluent	50	--	60	52	46	54
% Change	29	--	21	19	23	33
COD, mg/l:						
Influent	--	--	--	--	90	86
Effluent	--	--	--	--	47	54
% Change	--	--	--	--	48	37
Total Phosphate, mg/l P:						
Influent	1.35	1.60	1.90	2.05	2.10	2.00
Effluent	1.00	1.00	1.00	1.65	1.50	1.50
% Change	26	38	47	20	29	25
Orthophosphate, mg/l P:						
Influent	1.20	1.40	1.80	1.90	1.85	1.80
Effluent	0.85	0.90	0.95	1.40	1.30	1.25
% Change	29	36	47	26	30	31
pH:						
Influent	7.28	7.25	7.28	7.31	7.32	7.23
Effluent	7.16	7.19	7.02	7.23	7.12	7.13

APPENDIX B
FINAL PHASE OPERATIONAL DATA
(CONT'D)

Run No.	86	87	88	89	90	91
Duration, Hours	4.0	5.5	5.0	3.0	3.0	2.5
Flow, GPM	350	350	350	350	350	350
1000 Gallons Filtered	84	116	105	63	63	52
Filter Pressure Rise, PSI	1.9	1.5	1.9	1.9	1.9	1.9
Sample Temperature, F	76	76	77	78	78	78
Alum Input, mg/l	81	32	97	117	117	130
Turbidity, JTU:						
Influent	25	15	28	32	36	53
Effluent	9	9	7	9	17	11
% Change	64	40	75	72	53	79
Suspended Solids, mg/l:						
Influent	35	25	35	40	45	70
Effluent	15	15	10	15	30	25
% Change	57	40	71	62	33	64
BOD ₅ , mg/l:						
Influent	74	--	70	76	86	86
Effluent	54	--	58	52	55	34
% Change	27	--	17	32	36	60
COD, mg/l:						
Influent	90	--	96	129	166	161
Effluent	51	--	52	94	118	39
% Change	43	--	46	27	29	76
Total Phosphate, mg/l P:						
Influent	1.80	2.05	2.75	2.20	2.10	2.60
Effluent	1.25	1.50	2.20	1.50	1.40	2.10
% Change	30	27	20	32	33	19
Orthophosphate, mg/l P:						
Influent	1.65	1.90	2.40	2.05	1.90	2.15
Effluent	1.10	1.35	1.90	1.40	1.25	1.60
% Change	33	29	21	32	34	26
pH:						
Influent	6.98	7.21	7.25	7.08	7.04	6.85
Effluent	6.79	7.17	7.01	6.82	6.86	6.68

APPENDIX B
FINAL PHASE OPERATIONAL DATA
(CONT'D)

Run No.	92	93	94	95	Averages 62-95
Duration, Hours	4.5	4.5	3.5	4.0	3.7
Flow, GPM	350	350	350	350	350
1000 Gallons Filtered	94	94	74	84	77
Filter Pressure Rise, PSI	1.9	1.9	1.9	2.1	1.8
Sample Temperature, F	79	80	78	79	--
Alum Input, mg/l	130	162	162	162	100
Turbidity, JTU:					
Influent	34	41	32	38	30
Effluent	18	24	19	24	12
% Change	47	41	41	37	60
Suspended Solids, mg/l:					
Influent	45	55	40	50	40
Effluent	30	35	30	35	20
% Change	33	36	25	30	50
BOD ₅ , mg/l:					
Influent	72	86	94	88	75
Effluent	34	46	52	52	47
% Change	53	47	45	41	37
COD, mg/l:					
Influent	145	114	157	165	131
Effluent	114	61	112	121	77
% Change	21	46	29	27	41
Total Phosphate, mg/l P:					
Influent	2.20	2.55	2.25	2.40	2.61
Effluent	2.00	1.90	1.50	1.80	2.06
% Change	9	25	33	25	21
Orthophosphate, mg/l P:					
Influent	1.95	2.30	2.00	2.20	2.23
Effluent	1.80	1.70	1.30	1.70	1.71
% Change	8	26	35	23	23
pH:					(Range)
Influent	6.98	6.91	7.35	7.01	6.85-7.53
Effluent	6.86	6.76	7.19	6.80	6.68-7.39